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Innovation Modes, Determinants and Policy Effectiveness; A firm level empirical study using the UK CIS 4, 5 and 6

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Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Abbreviations

ABI	Annual Business Inquiry
ARD	Annual Respondents Database
ATT	Average Treatment on the Treated
CDM	Crepon, Duguet and Mairesse (1998)
CIS	Community Innovation Survey
EIS	European Innovation Scoreboard
EU	European Union
FDI	Foreign Direct Investment
GB	Great Britain
GDP	Gross Domestic Product
IDBR	Inter-Departmental Business Register
IP	Intellectual Property
IV	Instrumental Variable
N	Sample size
Mfr	manufacturing
Mfx	marginal effects
MNE	Multinational Enterprise
OLS	Ordinary Least Squares
ONS	Office of National Statistics
R&D	Research and Development
RBV	Resource Based View
SCA	Sustained Competitive Advantage
SIC	Standard Industrial Classification
SME	Small and Medium Enterprise
UK	United Kingdom

1. Introduction

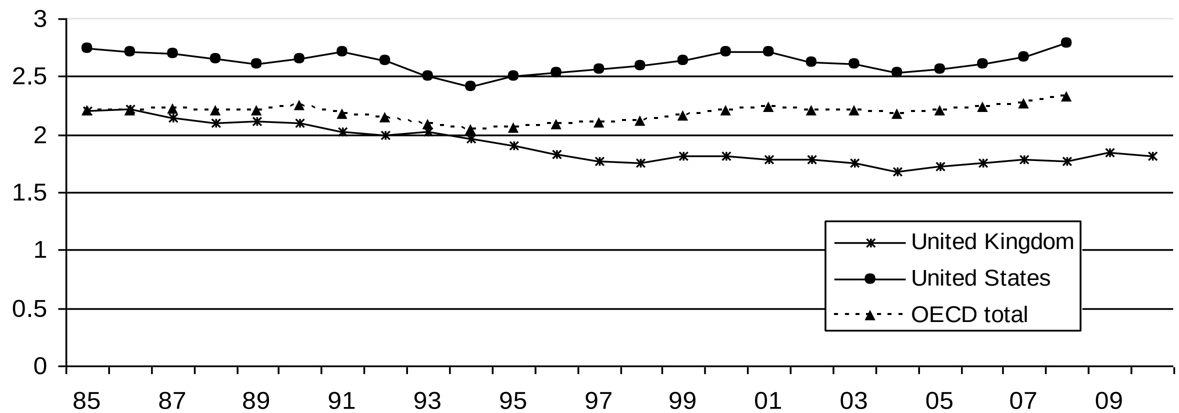
1.1. Poor Innovative Performance of the UK?

The relatively low R&D spending of EU countries compared to the US is perceived by some scholars and more widely by policy makers as a potential long run structural problem reflecting poor technological capabilities of the EU (Lisbon Strategy, 2000; Denis, Mc Morrow, Röger and Veuglers, 2005; Crescenzi, Rodriguez-Pose and Storper, 2007). Griffith, Huergo, Mairesse and Peters (2006) in a similar vein noting that post war growth in Europe was based on imitation and capital accumulation, argue that it is now required for Europe to grow based on its own innovation. The "European Action Plan 2010" with the specific aim to increase R&D spending from 1.9% of GDP in 2002 to 3.0% of GDP by 2010 (Lisbon Strategy, 2000) exemplifies the political resolve to overcome the perceived weakness in innovative performance of the EU. Likewise the UK industrial strategy highlights the importance of science and innovation in the face of globalisation (HM Treasury, 2005). This policy paper outlining the 10 year Science and Innovation Framework for the UK sets the target to increase R&D spending to 2.5% of GDP by 2014, already a notably more conservative goal then that set out by the Lisbon Strategy. Despite the corresponding government efforts, EU and UK R&D spending have while increasing somewhat, not improved sufficiently in the past few years to realistically meet these targets (see figure 1.1). In 1998 the R&D spending of the UK as percentage of GDP was at 1.76%, in 2010 (2008) at 1.82% (1.77%), compared to the OECD average of 2.33% in 2008 (the most recent available figure) and in 2.12% in 1998 (OECD Factbook, 2012).

These numbers put a question mark over the effectiveness of government intervention in this area and related to that the policy makers and possibly scholarly understanding of innovation. Indeed it is argued that such comparisons neglect that innovation consists of more than just R&D spending and patents[1].

[1] R&D is only an innovative input which does not necessarily translate to innovative outputs. On alternative measures of innovative activity the UK performs relatively well (Nesta, 2006). For instance according to the European Innovation Scoreboard (set up under the Lisbon Strategy) the UK has improved its relative position within the EU since its introduction in 2001 (European Commission, 2009).

Figure 1.1, R&D spending as % of GDP (OECD Factbook, 2011)



The reason why such figures suggesting low innovative performance are cause for concern is that innovation is the main driver of growth and competitiveness. This is evidenced by the endogenous growth literature (Romer, 1986, 1990; and Aghion and Howitt, 1992)[2] as well as international trade models (Krugman, 1979; Grossman and Helpman, 2001) in which the effects of innovations are dissipated through knowledge spillovers that happen due to the public good nature of innovations. Growth is so important because all problems of static efficiency, that is concerns about efficient market operation are insignificant[3] compared to considerations of dynamic efficiency in the long run (Cohen and Levin, 1989). This dichotomy among static and dynamic efficiency and the resulting ad hoc nature in which equilibrium models can account for technological change have led researchers to start of afresh in building theories of innovation away from mainstream economics. A major reason for the departure is the realization that innovation is essentially the very disruption of equilibrium, driven by the heterogeneity of characteristics and behaviour of economic agents, a view that is in stark contrast to neoclassical thinking. While models and theories that account for the dynamic and heterogeneous nature of innovation have flourished they have also highlighted the need for detailed

[2] See for instance Fagerberg (1994) for a comprehensive review of the literature on the relation between technology and growth.

[3] Though as growth effects accrue on them they are not to be neglected. Likewise discounting of future incomes is going to make them less substantial in present value terms.

information about the innovation process to help flesh these out, specifically with the use of firm level studies (Klette and Kortum, 2004).

1.2. Contribution and Chapter Summary

The motivation for this thesis is to provide empirical evidence based on the recently available UK CIS data in 3 areas that have not yet been investigated and are important for characterising and thus understanding the innovation process. Firstly this thesis aims to identify modes of innovation[4]. This is done using factor analysis which investigates the correlation among the information contained in the CIS to see to what extent certain properties of firms are related and can be characterised as strategies of innovation. Secondly the impact of determinants of innovation that is factors driving innovation inputs and outputs is to be estimated, this approach relies on the widely popular methodology put forth by Crepon, Duguet and Mairesse (1998). Thirdly the thesis examines the effectiveness of financial public support towards innovation, information about which is available in the CIS 4 and the CIS 6. So to speak this allows judging whether public support is an important determinant of innovative activities as well or whether it is ineffective. It also permits to establish which firms are more likely to be in receipt of public support and thus whether government policy is in line with its objectives. Furthermore in this thesis a measure of absorptive capacity for the CIS is created, a property that has recently been identified as a crucial for innovation (Cohen and Levinthal, 1990), to see whether this proxy contributes in explaining innovative activities and the receipt of public support towards innovation. Similarly a measure of appropriability is generated for use as an explanatory variable in the chapter on the determinants of innovation. Both of these measures permit to find out if their latent variables have nonlinear effects in explaining propensity and extent of innovative spending.

Besides the empirical evidence gained, the contribution of this thesis lies in examining several CIS survey rounds together. For one this serves as a robustness check for the conducted applications and on the other hand it allows investigating

[4] Though two studies on modes of innovation using the UK CIS 4 have previously been undertaken by Lambert and Frenz (2008, 2010) this work is distinct in methodology and findings to these.

the comparability of the survey rounds. This is of interest when putting side by side results identified for various survey rounds as well as for their use in panel and trend data analysis. For this work only the CIS 4, the CIS 5 and the CIS 6 are used. The first CIS survey only covered the manufacturing sector and has been interpreted as a pilot study due to considerable lack of coherence across the various surveys as conducted in specific countries in terms of definitions and sampling frames (Archibugi, 1994) and as a result it has not been made available to researchers by the ONS. The UK CIS 2 on the other hand consisted of different questionnaires for service and manufacturing sectors and only contained responses by 2,342 firms[5]. While the CIS 3 is a unified survey for services and manufacturing its response rates are fairly low relative to that of later survey rounds (42% compared to 58, 53 and 49% respectively). The 4th round of the UK CIS saw another overhaul of the survey. For one the extent of the industries covered has been increased to include 'sale, maintenance and repair of motor vehicles', 'retail trade, hotels and restaurants' as well as businesses falling under the 'other business activities' category according to SIC industrial classification. Thereby the coverage of service sectors was substantially extended making the survey more representative of the actual UK firm population. In numbers this meant that the underlying population increased to around 180,000 from previously 127,000 and correspondingly the sample of firms that were surveyed increased to 28,000 from previously 19,000. The second major change applied since the CIS 4 is that the question on whether firms carried out 'innovative activities' now relates to the whole of the survey period rather than just the last year besides a few other changes that have been applied to the survey design. Thus the CIS 4 is a natural cut-off point and the first panel achieved through cross-time linkage of units offered by the ONS also starts off with the CIS 4. It has to be noted though that the CIS 6 has also been modified compared to the previous version through rearrangement of the questions and directing many of the questions at innovation active firms[6] only. This means that care has to be taken when interpreting the statistics offered across the CIS 4, CIS 5 and CIS 6. The following survey round, the CIS 7 had just been made available when this work was finalized.

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[5] Details of this can be found in "A comparison of the second and third Community Innovation Surveys" by Marion Frenz (2002), DTI Economics and Statistics Report, no.3.

[6] Those that introduced a technological or wider innovation or that had undertaken innovative activities such as R&D spending during the survey period.

This chapter next summarizes the main contributions to the innovation literature. These start with the work of Schumpeter which stimulated the emergence of the evolutionary theory in the 80s. It then turns to the systemic perspective which is a recent extension of the evolutionary perspective particularly relevant for policy analysis. Another stream of literature that has dealt with innovation, albeit at times indirectly, comes from the business management literature. Namely the resource based view and the closely related notion of dynamic capabilities which are hence also shortly outlined. Next the fundamental link between knowledge as well as its specific characteristics and innovation is described. This is followed by providing a definition of innovation highlighting the importance of its non-technological aspects. This literature review is rounded of by making note of the recent empirical works based on the UK Community Innovation survey. From this discussion of the innovation literature it will be clear that there are still gaps in our knowledge as suggested previously. Specifically because evidence about the innovation process needs to be collected for individual countries as it is largely influenced by the national innovation system in which it takes place. This chapter is rounded of by a summary of the individual chapters of this thesis.

1.3. Literature Review and Definition of Innovation

It was Schumpeter (1934) who first pointed to innovation as the main driver of economic change and extensively investigated its role. He describes innovation as new combinations of productive resources which result in:

1. the introduction of new goods
2. the introduction of improved or new methods of production
3. the opening of new markets
4. the conquest of new sources of supply of raw materials or half-manufactured goods, and
5. the implementation of new forms of organization

(Godin, 2002b). He also introduced the distinction of innovation into “creative destruction” and “creative accumulation” (Malerba, Orsenigo and Peretto, 1997; Pender, 2010). The former process results in “radical” innovations that require whole new approaches towards production and thus may result in incumbent firms being supplanted by new ones who find it easier to adopt a new technology or may have pioneered it themselves (Lazonik, 2005, Pavitt, 2005). The later process leads to “incremental” innovations which are the result of accumulated technological competence of the firm (Malerba, Orsenigo and Peretto, 1997; Pender, 2010). Freeman, Clark and Soete (1982), Kline and Rosenberg (1986), Lundvall (1992) point out that economically speaking incremental innovations may be more important than the initial innovation. Incremental innovations being the refinements of major innovations by definition occur a lot more frequently (Fagerberg, 2005). Radical innovations in its pure form are difficult to foresee and their ensuing incremental innovations can take decades to diffuse. An awareness of the potential to be supplanted if one does not keep abreast of market developments is likely to have led to the development of what is termed dynamic capabilities (Teece and Pisano, 1994).

Various strands of literature have contributed to our understanding of innovation. First and foremost evolutionary theory, which was influenced by Schumpeter’s view that economic dynamics are explained by continual innovation disrupting the economy from moving towards and optimal equilibrium state (Andersen, 2006). Nelson and Winter (1982) are the first to thoroughly formalize this view. Core to their models is competition among short-sighted firms that use innovation routines determined by technological trajectories. Firms being short-sighted means they have bounded rationality, a concept put forth by Simon (1959, 1959) and Cyert and March (1963). So due to limited cognitive ability of economic agents and related to that the increasing costs of acquiring information firms follow rules of thumb to guide their behaviour (Metcalfe, 1995). These so called routines for decision making can be shed as they are found to be of no more use and new ones are acquired (Witt, 2008). The overall interplay of mutation, selection and retention then determines economic activity. Another major contribution in line with this thinking comes from Rosenberg and Kline (1986) who put forth the chain linked model of innovation.

The last stage of the evolutionary process has also been studied under the term diffusion, which Hall (2004) defines as “the process by which individuals and firms in a society/economy adopt a new technology, or replace an older technology with a newer.". Diffusion involves learning as firms try to "copy"[7] and through this can have feedback effects on the diffused innovation itself generating further diversity and thus potential improvements (Kline and Rosenberg, 1986). This learning by firms (Malerba, 1992) is fundamental to the generation and dissipation of knowledge about new products and production technologies that are created in the economy (Metcalfe, 2007). It is a cumulative and path-dependent process (Dosi, 1988). As a result of the path dependent nature of knowledge accumulation, copying is not costless (up to 50-75% of the original invention, Mansfield, 1981; Levin et al., 1987), as one needs to have the right resources to do so, specifically absorptive capacity (Cohen and Levinthal, 1990). Thus Cohen and Malerba (2001) note that firms are distinct in "their histories, capabilities, strategic visions and perceptions", variety in the latter two being reinforced through uncertainty of firms about the future of markets and technologies. The tenets of evolutionary theory are thus technological cumulability, irreversibility, localized learning and externalities (Freeman, 1994).

The systemic literature is an extension of the evolutionary perspective concerned with the role of geography specific institutions, in other words the impact of the socio-economic context made up of laws, rules, norms and routines on technological progress. Edquist (1997) hence defines the innovation system as "all important, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations." (Edquist, 2005). The systemic perspective has evolved as a result of criticisms to the market theory and thus provides an alternative guide to policy making. Justification for intervention is provided on the grounds that governments have a better ability to coordinate across institutions (Metcalfe, 1995) being aware of interdependencies of policy aims and potentially systemic failures (Asheim and Smith and Oughton, 2011). Appreciative of the dynamic nature of innovation the systemic perspective identifies that "successful economies are those which have robust, but adaptable, network connections that enable organizations to translate new knowledge into viable

[7] As Hall (1994) notes imitators often follow different approaches and hence have to be innovative themselves (Lööf and Heshmati, 2006).

innovations and enhanced productive capacity" (Dodgson, Hughes, Foster and Metcalfe, 2011). While Soete, Verspagen and ter Weel (2009) argue that due to the increasing role of services "access to state-of the art technologies" becomes more important than advances in science and technology. Overall the systemic perspective draws attention to firms' environments. This is somewhat in contrast to the next strand of literature that focuses on firm characteristics.

The resource based view (also abbreviated as RBV) is part of the management literature concerned with firm strategy aimed at generating a sustained competitive advantage[8]. Its foundations are traced to Penrose's (1959) work on the growth of firms. In her view, firms are "bundles of technology, capital and labour" and she argues the "bundling" to be unique for each firm which explains their varying growth rates. Hence her theory draws attention to the heterogeneous nature of firms despite homogeneous outputs. Only starting with the work of Barney (1991) has the RBV literature really taken off. In this article Barney (1991) identifies firm specific resources as the source of "Ricardian rents"[9] and lays out more thorough foundations of the RBV (Barney, Ketchen and Wright, 2011; Kraaijenbrink, Spender and Groen, 2010). Which Locket, Thompson and Morgenstern (2009) recently define as the theory about "the relationships between the opportunity set facing the firm, the strategic behaviour to be implemented by managers and the outcome in terms of competitive advantage or performance". The contribution of the RBV lies in characterising resources which are "semi-permanently" tied to a firm (Wernerfelt, 1984) and thus help to sustain a competitive advantage. Barney (1991) identifies the following properties of these resources allowing for SCA, they need to be valuable, rare, imperfectly imitable and non-substitutable. Other properties that have been identified are non-tradability (Dierickx and Cool, 1989) and idiosyncraticness (Williamson 1979, Katkalo, Pitelis and Teece, 2010), most of the aforementioned properties refer to intangible assets (Barney, 2001; Wernerfelt, 1984; Teece, 1998; Katkalo, Pitelis and Teece, 2010). The major ones being tacit

[8] SCA definition: firm that "is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy.". Empirical evidence for SCA is found in Cool and Schendel (1988), Jacobsen (1988) , Hansen and Wernerfelt (1989) and Barney (1991), Rumelt (1991).

[9] Earnings of economic resources above their average or value.

know how and reputation (Teece, Pisano and Schuen, 1997), human resources, entrepreneurship and marketing (Barney 1991, Barney, Ketchen and Wright, 2011).

However not the resources as such but eventually how they are used is paramount, which is as Amit and Shoemaker (1993) put it, down to “discretionary managerial decisions about resource development and deployment” (Wernerfelt 1984; Teece, Shuen and Pisano, 1997ö Mikado, 2001). Amit and Schoemaker (1993) define capabilities as “a firm’s capacity to deploy resources, usually in combination, using organizational processes, to affect a desired end” and they “are based on developing, carrying, and exchanging information through the firm’s human capital”. These aspects have been more explicitly dealt with by Teece and Pisano (1994) and Teece, Pisano and Shuen (1997), Eisenhardt and Martin (2000) who put forth the notion of “dynamic capabilities” which allow incumbent firms to “survive” creative destruction. Dynamic capabilities are thus defined as “the ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments” (Teece, Pisano and Shuen, 1997). While Barreto (2010) notes that the role of dynamic capabilities is to “integrate, build and reconfigure internal and external competences”, this is done through path dependent routines and organizational learning[10]. A resource that has been identified as an important dynamic capability but that has not emerged directly from this literature is absorptive capacity[11] (see Zahra and George, 2002 for a review).

The role of knowledge in the context of an innovation production function is epitomized in a widely cited article by Pakes and Griliches (1984). Their knowledge flow framework depicts the relationship of R&D, innovation and productivity. Here knowledge is the underlying latent variable that drives innovation. Malerba and Orsenigo (2000) point out that knowledge impacts economic activity through diffusion as well as through its recombination that leads to innovation, both

[10] See for instance Winter and Zollo (2002) on the role of organizational learning for dynamic capabilities.
[11] Cohen and Levinthal (1990):”Thus, some organizations (like Hewlett-Packard and Sony) have the requisite technological knowledge to respond proactively to the opportunity present in the environment. These firms do not wait for failure on some performance dimension but aggressively seek out new opportunities to exploit and develop their technological capabilities.” This description of absorptive capacities can also be thought of as an appropriate definition of dynamic capabilities.

processes being highly interlinked. Arrow's (1962) observation that knowledge is neither fully appropriable nor a perfect public good was ignored for some time by economists (Levin, 1988). Having public good nature implies that knowledge has social benefits that exceed private ones, which is the result of it spilling over to other agents besides its original owner or conceiver (Nelson, 1959). This provides a rational for government intervention from the market perspective through the use of IPRs, public procurement, funding research and education and subsidizing capital goods. The latter is because of 'rent spillovers' that occur due to knowledge that is embedded in capital goods[12] and purchased by users below their economic value on the other hand 'knowledge spillovers' can also take place as a result of non-market interactions (Griliches, 1992). Knowledge spillovers have been distinguished as MAR[13] (Marshall, Arrow and Romer) and Jacobian externalities (see for instance Harris, 2011 for a review). The first are considered to arise due agglomeration of firms from the same industry where face to face interaction among workers of different firms helps dissemination of knowledge[14] and similar effects occur through the generation of specialized common labour pools. Jacobian externalities on the other hand are spillovers across distinct but related industries that have co-located thereby facilitating the diffusion of more generic knowledge as found in so called innovation clusters (Malmberg and Power, 2005)[15].

To Polanyi (1958; 1966) knowledge is seated within agents. He uses the term "tacit" to describe this sort of knowledge (Cowan, David and Foray, 2000; Johnson, Lorenz and Lundvall, 2002; Antonelli, 2009). On the other hand codified knowledge[16] is knowledge that is specified in ways so as to be easily understood by anyone. Both types are complementary and as Johnson, Lorenz and Lundvall (2002) point out they are ideal states, thus all knowledge has mixed characteristics. The use and production of tacit knowledge is essential for maintaining the competitive position of a firm (Asheim and Gertler, 2005). Similarly Nonaka (1994) and Nonaka and Takeuchi (1995) argue the role of organizations is to draw on individual tacit

[12] This sort of spillover is also relevant for international knowledge transfers (see Castellacci, 2008).
[13] The term was coined by Glaeser, Kallal, Scheinkman and Schleifer (1992).
[14] Where agents share a common language, technology culture, etc (Jaffe, 1989; Audretsch and Feldman, 1996).
[15] Boschma (2005) argues other dimensions of proximity are also relevant, these include: cognitive, organizational , social and institutional.
[16] Polanyi (1958; 1966): "knowledge explicit in conscious cognitive process" (Cowan, David and Foray, 2000).

knowledge, interact it with the knowledge base of the firm and thus in order to create knowledge, shared cognition and collective learning are essential (Lam, 2005). The transfer of tacit knowledge requires either codification of knowledge which is costly (Teece, 1998) or a transfer of people, so it requires actors to be close in proximity both in terms of geographic[17] as well as technological space[18]. Lundvall and Johnson (1994) classify knowledge according to the mechanisms and channels through which it is acquired into know-what, know-why, know-who (when and where) and know-how[19]. While the first two modes are acquired by accessing knowledge sources (which must hence be more codified in nature) the other two are related to practical experience (which thus relates to the tacit dimension). A similar distinction has been identified by Metcalfe (1995) between ‘fundamental knowledge’ that can scientifically be verified and ‘applied knowledge’ which is “focused on particular generic productive transformations”. Malerba and Orsenigo (2000) note that beyond technological knowledge one also needs to have knowledge about “applications, users and demand”. In line with this Lundvall and Johnson (1994) conclude that knowledge is generated through an interactive process[20] relating it to the systemic perspective and asserting that the mixed economic system is paramount for the generation of innovation due to its non-market aspects such as human relationships and institutions[21].

The Oslo Manual (OECD and Eurostat, 1997) states that: “A technological product innovation is the implementation / commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation / adoption of new or significantly improved production or delivery methods.”. Stoneman (1995) points out though “that one firm’s product innovation may be another firm’s new process innovation”. The classic generator of innovation outputs

[17] Breschi and Lisano, 2001a and Castellacci, 2008 provide reviews of the literature on geographic spillovers.
[18] See Rosenkopf and Almeida, 2003, Harris and Li, 2006 and Harris and Moffat, 2011 for short reviews.
[19] Similar distinctions can be found in the management literature, see for instance Malerba (1992) or Grant (1996) for a taxonomy of the types of learning (doing, using, from advances in science and technology, inter-industry spillovers, by interacting, by searching).
[20] As in Kline and Rosenberg (1986) chain linked model of innovation.
[21] Toedling, Lehner and Kaufmann (2009) provide a review of how different innovation types need differing knowledge sources and links but also their complementarity.

is considered R&D which is defined in the Frascati manual (OECD, 1963)[22] as "the production of new knowledge and new practical applications of knowledge". The Oslo manual (OECD and Eurostat, 2005) which heavily influenced the design of the CIS considers further activities to be "innovative", these include: expenditure for the acquisition of external knowledge, acquisition of machinery and equipment, training activities related to innovation (or with the aim of innovation), design and activities related to the market introduction of innovations. Edquist (2005) contends one needs to look at all factors together in part because it is not known which factors are the important ones for innovation. These include "competence building in the labour force", "formation of new product markets" and "user feedback and interactions" which are closely related to innovative inputs such as training and marketing (Bloch, 2007). "Market introduction of innovations" and "design spending" are further complementary innovative inputs (Teece, 1986) to facilitate acceptance and recognition of the innovative output as such by the consumer.

Acknowledging that innovation takes place through feedbacks and is thus a complex process has meant that its non-technological dimensions are now increasingly recognized, though already Schumpeter had noted the organisational dimension of innovation[23]. Likewise the RBV has pointed to the role of organization of human and physical resources for competition. Organisational (or wider) innovation is often argued to be a "pre-condition" or "complement"[24] to successful innovation, to be able to take advantage of technological developments (Bloom and Van Reenen, 2007; Edwards, Battisti and Neely, 2004; Wengel, Lay, Nylund, Bager-Sjoegren, Stoneman, Bellini and Shapira 2000; Lam, 2005). As a result organisational[25] and marketing innovations are now included in the definition of innovation in the third edition of the Oslo manual (OECD and Eurostat, 2005). Wengel et al. (2000) distinguish these into structural innovations concerned with the organisational form

[22] "The standard practice for Surveys of Research and Experimental Development"
[23] See for instance Siqueira and Cosh (2008), Battisti and Stoneman (2010) and Evangelist and Vezzani (2010) for empirical evidence on the role of organizational innovation.
[24] Geroski, Machin and Van Reenen (1993), Cozzarin and Percival (2006), Jensen, Johnson, Lorenz and Lundvall (2007), provide empirical evidence that firms using both technological and organizational innovation outperform those firms that just do either one of these.
[25] These include aspects of business practices, workplace organisation, external relations (procurement, distribution, recruitment and ancillary services).

of firms versus division of labour and managerial innovations on the other hand concerned with operations and procedures through which firms organise their activities such as the responsibility of personnel and information flows. As Bloch (2007) as well as Tether and Tajar (2008) stress organisational innovation is a feature specifically observed in the service sectors where the scope for technological innovation is limited and instead work procedures and practices are adjusted. Thus this sort of innovation has gained in prominence in developed economies[26] due to increasing share of service sector where it generates around two thirds of the GDP (Salazar and Holbrook, 2004).

To conclude, the heterogeneity of firm activities, their complementarity as well as the bounded rationality of agents highlights that a linear view of innovation including the notion of a technology frontier is not ideal for the analysis of innovation. However empirical methodologies available are still limited to this sort of perspective and so is the Community Innovation Survey through its design. As a result this thesis may not take full account of the wider view of innovation that has just been discussed. It also neglects the role of innovation in developing countries which are of a distinct nature due to their different systemic settings and firm specific capabilities.

Nevertheless the Community Innovation Surveys, firm level innovation surveys conducted in the EU countries[27] are a major step to further the understanding of the nature of innovation at the firm level. These surveys provide an exhaustive coverage of enterprises and as they are carried out regularly allow for cross country comparisons, besides that they provide the potential for the future to analyse changes in innovative activities as they are collected repeatedly over time. Hence investigating the country specific context and dynamic nature of innovation is possible, both major tenets of the theoretical innovation literature. A set of published studies exists based on the UK CIS. The ones that have been identified start with Tether (2002) who explores why firms corporate using the CIS2. Frenz and

[26] The role of innovation has also been shown important in catching up, to achieve this a mix of "copying" or diffusion of technology and "organizational innovation" has been shown to be of particular importance in the past success stories (Fagerberg and Godinho, 2005).
[27] As well as Norway and Iceland.

Ietto-Gillies (2007) analyse the effect of multi-nationality on the likehood of innovating using the CIS 2 and CIS 3 (panel) and in another study (Frenz and Ietto-Gillies, 2009) examine the effect of using internal or external sources of knowledge on innovative outputs, likewise based on CIS 2 and CIS 3 (panel). Harris, Li and Trainor (2006) estimate the impact of determinants of R&D activities for Northern Ireland to assess the usefulness of increasing the R&D tax credit. Griffith et al. (2006) also relying on data from the third CIS round apply the CDM methodology to compare the estimates of the model for the UK with those of other European countries. Lambert and Frenz (2008, 2010) have used the UK CIS 4 to study modes of innovation. Another contribution based on the UK CIS is the work by Canepa and Stoneman (2008) which is concerned with the likehood of experiencing financial constraints when innovating making use of the CIS 2 and the CIS 3. D'Este, Iammarino, Savano and Von Tunzelmann (2009) using the CIS 4 investigate the barriers of innovation experienced by non-innovators compared to innovating firms. Harris and Li (2009) based on the third round of the UK CIS, look into the relationship of innovation and exporting. In a later paper Harris and Li (2011) relying on the CIS 4 estimate the determinants of participating in export markets and carrying out R&D. Love, Roper and Hewitt-Dundas (2010) using the CIS 4 establish the contribution of determinants of innovation for the Northern Irish service sector specifically taking into account the intra-extra regional connectivity as well as examining how this in turn impacts exporting and productivity, lastly the work by Battisti and Stoneman (2010) explores the relationship between organizational and technological innovations making use of the fourth round of the Community Innovation Survey. These studies exemplify the width of applications the CIS has found but also that due to its novelty not too many works exist for the UK using the CIS data.

1.4. Chapter Summaries

The thesis consists of six chapters including the introduction and the conclusion. The second chapter is a description of the Community Innovation Survey. The measurement of innovation in the past relied on R&D spending and patent data collection at the national level, this undertaking has evolved through inception and use of detailed firm level surveys. While the CIS represents a major step in advancing our understanding of the complexity of innovation, areas that may require improvements are noted, such as accounting for non-technological innovations. The specifics of the UK CIS datasets under scrutiny in this thesis are then described. The changes that have occurred in its design across the last three survey rounds are highlighted. These impede comparisons of many of the provided statistics across survey rounds particularly because they are likely to have led to different types of measurement errors which the sometimes substantial differences in the observed statistics across the surveys seem to confirm. There are also instances where changes may have been towards the wrong direction which is pointed out. Two more issues of the survey, the response bias and non-response to certain questions are also discussed before turning to a comparison of the basic data statistics across the surveys. This analysis is important because previous studies have not investigated the comparability of the UK CIS surveys.

The third chapter more thoroughly analyses the information the CIS provides, this is done in two ways. One is the generation of absorptive capacity and appropriation measures derived through factor analysis of the question sets on 'information sources used for innovation' and 'appropriation methods' respectively. How these two factors influence the extent to which knowledge spillovers take place is also discussed. Secondly the chapter identifies modes of innovation likewise based on factor analysis but this time for the questions found in the CIS that can be interpreted as part of a strategy followed by firms. This chapter is complemented by a literature survey of works that have followed a similar approach as well as a section on the methodology behind factor analysis. The effect of the absorptive capacity and appropriation measures generated in this chapter in the context of the next two chapters has not been previously investigated by the literature. Secondly the approach for the generation of modes of innovations followed in this chapter has not been applied to the UK CIS data and thus provides news evidence as to the innovation modes that firm's exhibit.

A more long standing method for analysis of this sort of survey data is presented in the next chapter. The methodology that is detailed consists of three reduced form equations. The first explains which firms undertake R&D and the extent to which they do so. Instrumented R&D spending, a proxy for knowledge capital is used in the second equation in explaining the likehood of generating various types of innovation. The last equation explains the contribution of innovative outputs to firm productivity. The absorptive capacity and appropriation measures generated in the previous chapter are used as explanatory variables in this analysis as they are believed important determinants of innovative activities. As they are continuous in nature it allows to test whether there are decreasing returns to these factors. Lastly and most importantly this chapter contributes to the literature as there is no work based on the UK CIS which covers the service sector, nor is there any study based on the CIS survey rounds investigated herein.

The fifth chapter looks at whether government support towards innovation is effective. First the reader is presented with a review of the literature investigating this issue. The approach followed in this chapter to this end is to use a propensity score model to generate a balanced sample. The factors that are likely to influence the receipt of public support are also discussed in this chapter. For each supported firm a similar firm which does not obtain public support for innovation is found and the innovative performance of the treated and matched sample is then compared. Also the propensity model predicting the likehood of receipt of support makes use of the previously generated absorptive capacity measure to investigate its and a set of other factors importance in determining the receipt of public support. This also helps to identify to what extent government support is able to reach specific firms in line with its policy objectives. No previous studies have directly investigated the effectiveness of financial public policy support for innovation in the UK particular in light of introduction of the R&D tax credit in 2000 for SMES and 2002 for all firms. Nor do there exist studies that look at the impact on innovative performance measures besides R&D spending intensity, in fact most only employ samples of firms that actually carry out R&D.

1.5. Conclusion

This Chapter has pointed out that innovation is important for the growth and competitiveness of a country. The exact nature of innovation process is yet to be fully understood though. It is believed to be driven by heterogeneous characteristics and behaviour of agents that are specific to a country's systemic context. It is thus that empirical research based on the UK Community Innovation Survey is motivated. This UK wide survey provides detailed information about the innovative activities of firms based on an extensive sample of firms. This thesis is specifically concerned with analysing modes of innovations, its determinants and the effectiveness of public support towards innovation. At the same time it investigates to what extent the recent CIS survey rounds are comparable.

2. The CIS Data

2.1. Introduction

In the 70s economists started to take an in interest in innovation attempting to explain and thus find ways out of the prevailing recession. Scholars resorted to the widely available R&D and patent figures as measures of technological progress and showed its importance for economic growth through driving productivity (see for instance Griliches, 1979; Lichtenberg and Siegel, 1991; Helpman and Coe, 1995; Eaton and Kortum, 1996; Griliches, 1998, Griffith, Redding and Van Reenen, 2004). Goodhart's law however implies that the correlation among a measure and its latent variable decreases with increasing efforts to stimulate the former. This is a result of policy using cheap ways to stimulate the index which do not necessarily effect its underlying fundamentals (Freeman and Soete, 2009). Hence a narrow focus on one or two measures of innovativeness is likely to lead to a breakdown of the relationship among the measure(s) and actual innovative performance. The 80s in line with this notion saw a paradigm-shift away from the simple linear input output model towards more complex theories of innovation due to criticisms initiated by Rosenberg (1976, 1982) and Kline and Rosenberg (1986)[28]. To test and flesh out these theories alternative ways to measure innovation and more broadly the factors that characterise and are believed to influence innovative performance were required. Various approaches have been devised to this end including the collection and analysis of the SPRU database and more recently the introduction of the European Innovation Scoreboard and the CIS. Nevertheless while differing measures have evolved, to date R&D spending figures as proportion of GDP are still the most prominent indicator used by governments to gauge their innovative performance (Godin, 2004 provides a review).

All methods of measuring innovation have advantages as well as shortcomings, each being helpful in identifying different facets of innovation. The aim of this chapter is to point to the strengths of the CIS as well as its limitations and describe its evolution over time. Part of the changes that are described have addressed

[28] Also refer to Bell and Pavitt (1993) on the relation of invention, innovation and diffusion.

weaknesses but some of them pose serious problems to the comparability of the surveys and thus their use for trend or panel data analysis. So this chapter describes the Community Innovation Surveys 4, 5 and 6 paying particular attention to modifications of their design and content. It also provides descriptive statistics, showing differences in the means of the variables it contains across surveys. No previous study has made a detailed comparison of the survey rounds. However analysis of innovation as it takes place over time is an important reason why the CIS has been established as a periodic survey. This chapter thus contributes to the literature by providing an assessment of the usefulness of the current CIS surveys for research on innovation (as it takes place over time).

The structure of this chapter is as follows. The second section after touching on various methods of gauging innovation explains how the CIS overcomes some of the problems with these approaches. It then turns to shortcomings of the CIS from a theoretical perspective as well as changes that have been implemented to surmount these. The third section provides a description of how the CIS is collected and what information it contains specifically making note of apparent inconsistencies in the reported underlying population. These are “fixed” by reweighting the strata according to the population which the ONS reports to underlie the CIS 5. Hence the populations the surveys represent and subsequent analysis should be more comparable. The fourth section then highlights the changes to the survey design that occurred over the last three survey rounds which are expected to limit comparability. Descriptive tabulations of the data contained in the last three survey rounds are presented in the fifth section with the final section concluding the chapter. The appendix, section 7, describes the data cleaning that has been applied.

2.2. CIS Strengths, Limitations and Improvements

R&D figures and patent data as measures of innovative performance have the advantage of being available for a long time. For the former it is however difficult to specify the types of spending to be included[29] (Smith, 2005) and it is only an innovative input that does not necessarily translate one to one into outputs (Cohen, 1995; Kleinknecht et al. 2002). The same applies for patents which like R&D are not equally useful across all sectors[30] and likewise do not to the same extent translate into economic value generated (Patel and Pavitt 1995, Kleinknecht et al. 2002, Smith, 2005). Furthermore as Rosenberg (1976, 1982) points out the diffusion of technologies requires additional resources by firms and thus R&D not just leads to new outputs but is essential for imitation[31] which thus further weakens its relation to actual innovative outputs. Beyond the complex interaction effects as presented in the chain linked model of innovation by Kline and Rosenberg (1986) which cannot be captured by merely a singular R&D spending figures, sole reliance on these figures thus neglects the importance of other innovative inputs such as design, engineering, experimentation, training and exploration (Smith, 2005)[32] and their interactions. Thus not all innovation necessarily requires prior (observable) R&D, particularly in the service sector where other forms of innovative activities where specifically organizational innovation has been identified as important (Tether, 2002). Furthermore small firms often have no reported R&D spending, as their activities are not very formalized (Schmookler, 1959; Pavitt, Robson and Townsend 1987, 1989)[33] thus R&D figures are likely to underreport innovative activities in small firms. The CIS addresses these concerns by including information about a wide range of innovative activities even if only carried out as informal activities (ie no accounting figures available) as well as to some extent wider forms of innovation. Furthermore it collects data about cooperation partners and information sources used and thereby is better suited to account for the complex nature of the innovation process. Lastly by collecting data at the firm level it can account for the

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[29] The Frascati manual (OECD, 1963) which is a guideline proposed by the OECD for measuring R&D considers three types of activities to constitute R&D, that is basic research, applied research and experimental development. Particularly difficult for this measurement is the distinction among research and development and scientific and technological services as well as the distinction between novelty and routine (Freeman and Soete, 2009).

[30] Cohen, Nelson and Walsh (2000) show that in most industries secrecy and first mover advantage are more important.

[31] Fagerberg and Verspagen (2002) found that the costs of diffusion have increased. These costs arise due to the knowledge generation required for imitation and diffusion (Malerba, 1992). Hence these activities are considered an important part of innovation itself (Hall, 2004), also since they often lead to further incremental innovation.

[32] Mairesse and Mohnen (2010) provide sources of empirical evidence based on the CIS that these are important.

[33] Though the underreporting is not as extreme as suggested based on assessment of the value of the innovations generated by small firms presented by Tether, Smith and Thwaites (1997) and Tether (1998).

observed heterogeneity of firms in their innovative activities even within sectors (Nelson and Winter, 1982).

Djellal and Gallouj (1999) however question the usefulness of the Community Innovation Survey for services on the basis that services have distinct characteristics. For instance in services process and product innovations are more difficult to distinguish (Gallouj and Weinstein, 1997). Furthermore non-technological innovation such as marketing and organizational changes instead of technological process and product innovations represent the norm for service sectors (Salazar and Holbrook, 2004; Bloch, 2007; Tether and Tajar, 2008)[34]. This neglect of services as Tether (2001) notes is a result of the CIS initially being set up to collect information from manufacturing sectors[35] and only starting with CIS 2 service sectors were included without much adjustment to the survey[36]. As a result Djellal and Gallouj (1999) argue that the innovative performance of service industries is likely to be underestimated by the CIS. The reason for the initial bias towards manufacturing as Miles (1993), Salazar and Holbrook (2004) and Tether (2005) explain is that in the past services were perceived to contribute little in terms of innovation to the economy. Nowadays this perception is no longer held as services have been shown to be highly creative in non-technological areas of innovation (Miles, 2000; Hipp and Grupp, 2005)[37]. A consensus emerged to create surveys that reflect both innovative activity in services and manufacturing together. This is also because a separation of firms into manufacturing and service sector becomes increasingly difficult (Miles, 1993; Djellal and Gallouj, 1999; Drejer, 2004; Hipp and Grupp, 2005; de Vries, 2006; Bloch, 2007)[38]. Hence previously perceived differences in service sector innovative activities now help to capture the broader nature of innovation and thereby also benefit our understanding of innovation in manufacturing (Miles, 2000; Drejer, 2004; Salazar and Holbrook, 2004; de Vries, 2006; Bloch, 2007). Although services are now included in the CIS the criticism of it

[34] Kleinknecht, Van Montfort and Brouwer (2002) provide evidence that in services R&D spending is of less importance for generation of innovations then for manufacturing.
[35] Based on the first Oslo Manual (1992), 2nd Oslo Manual (1997) then included services.
[36] Though for the CIS 2 separate surveys were sent to manufacturers and services.
[37] This bias is also somewhat a result of less formalized innovative activities in the service sectors (Freeman and Soete, 2009).
[38] For a discussion of the different approaches on how to use surveys to measure innovation in services see for instance Salazar and Holbrook (2004) and de Vries (2006).

not properly accounting for innovative activities in services still holds to some degree. Specifically the aforementioned organizational and marketing innovations are not fully incorporated into the CIS (Godin, 2002b; Drejer, 2004; Bloch, 2007).

As noted the CIS does not capture well the non-technological aspects of innovation (Guellec and Mohnen, 2001)[39]. Details of this criticism can be found in Wengel, Lay, Nylund, Bager-Sjoegren, Stoneman, Bellini and Shapira (2000)[40] who point out that in part questions on non-technological innovation had not been included in the CIS simply because there was and probably still is no clear cut consensus of what it constitutes and how to operationalize this concept in the form of useful survey questions. In response to this criticism starting from the third round of the CIS a question set termed “wider innovation” concerning non-technological innovation has been included. This option had been assessed to be the cheapest but also least useful by Wengel et al. (2000)[41] as other components of the survey had not been adjusted accordingly to reflect this broader definition of innovation. The current Oslo Manual (Eurostat and OECD, 2005) now includes organisational and marketing innovation as part of its definition of innovation, albeit the implementation in the CIS of this extended definition of innovation as discussed in Wengel et al. (2000) is debatable[42]. Battisti and Stoneman (2010) confirm that activities falling under the heading of wider innovation in the CIS are complementary to traditional technological innovation[43]. However Bloch (2007) argues that information not only on whether organizational or marketing innovation took place is needed – as present in the CIS now - but also information on the organizational[44] and marketing

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39 As pointed out in the literature review in the introductory chapter as well as further discussed in the next chapter organizational innovation is complementary to technological innovation and both may reinforce one another, also see Bloch (2007).

40 This is a report commissioned by the EC on how to best adept current survey strategy to account for organizational innovation.

41 Though in the CIS 6 this is somewhat remedied by moving it from the end of the survey to the front after the section on “Innovative Activity” which means it is somewhat classified as innovative input. Though the literature does neither clearly classify it as a input nor as output.

42 Notably the CIS includes implementation of new/changed corporate strategy and advanced management techniques both which are not considered to fall under the definition of innovation under the latest Oslo Manual, on the other hand the rest of the CIS has not been adjusted to reflect that questions now refer to an extended definition of innovation.

43 Similarly Frenz and Lambert (2008) provide evidence on the positive impact of wider innovation on productivity.

44 Arundel et al. (2006) overcome this by linking the CIS with a survey on work organization that they have conducted.

procedures in place are required. Furthermore that more details on the role of consumer involvement needs to be collected. Another area that is neglected in the CIS surveys and which is particularly important for service sectors is human resource management (Hipp and Grupp, 2005; Bloch, 2007). Foss and Laursen (2003) and Arundel, Lorenz, Lundvall and Valeyre (2006) for instance provide accounts of the relationship between Human Resource Management and innovation.

Wengel et al. (2000) criticise that networked forms of innovation are not captured by the CIS. Likewise Salazar and Holbrook (2004) note that the Community Innovation survey despite the systemic rhetoric[45] of the Oslo manual is very much input output oriented rather than trying to understand the process of innovation including its diffusion as well as the influence of clusters in which it occurs. According to Godin (2002a) this is a result of the inherent bias of the OECD, that is statistical offices towards subject type approach surveys. Even though the object type approach[46] is acknowledged in the Oslo manual (1997) to be “a direct measure of innovation” it is neglected in favour of the subject type approach since it is “firms that shape the economic outcomes and are of policy significance”. The subject type pays little attention to the systemic context and assumes that firms are the main drivers of technological change (Hipp and Grupp, 2005). In response to some of these criticisms information on cooperation partners and sources of information important for innovation have been included starting from the third round of the CIS surveys[47]. Other criticisms applied to the subject type approach followed with the CIS is that it tends to focus on successful firms, firms that are innovatively active but have not generated an innovation during the survey period are neglected as a result of the “snapshot” methodology such surveys take (Salazar and Holbrook, 2004). The later criticism has been aggravated as firms without innovative outputs have increasingly being excluded from answering all of the

[45] See for instance Lundvall et al. (2002) and Edquist (2005) for reviews of the systemic literature.
[46] Archibugi (1988): Innovation surveys that are based around innovations aiming to detect their evolution and significance. On the other hand “subject type” approach surveys are centred and thus collected from the innovator, which in the case of the CIS is the reporting unit.
[47] Bloch (2007) argues to extend questions on sources of information to reflect where the information sources were located and thereby add to the understanding of clustering of innovative activities, this is also likely to interest scholars looking at international spillovers (see for instance Castellacci, 2008 for a review).

survey questions. However it is expected to be overcome to some extent with increasing rounds of surveys that allows to track firms that are sampled over time.

Harris (2002) contends that due constant resizing, acquisition and sale of business units using reporting unit data[48] over time is problematic (specifically for the generation of stock measures). Related to this he also points to the heterogeneity of plants that constitute an enterprise. Salazar and Holbrook (2004) concede that for the foreseeable future there is likely to be no conclusion as to what is the best unit of analysis for innovation surveys. Another important issue that Harris (unpublished) has discovered is that while the firms location in the UK CIS is defined by where its reporting unit is located this is not necessarily where the bulk of for instance its R&D is carried out. He has confirmed this bias exists using data from the ARD. This issue is relevant when investigating regional aspects such as spillovers and clustering (see for instance Harris, Li and Trainor, 2006 and Harris, 2011 for review of the literature on these concepts). Related to this aspect is the question of how to best make use of indicators of regional affiliation that are available. If it is geographical clusters that one wants to identify defining their dimensions is difficult, as Feldman (1999) notes “there is no understanding of the way in which spillovers occur and are realized at the geographic level”. Possibly as suggested by Bloch (2007) one could include questions as to where the enterprises sources of information where located, further they note that finer dimensions then presently available (the government head office region) need to be used in such a question.

The CIS relies on firms’ self-assessment as to what they consider to be an innovation and also as to what they consider to be R&D spending. A number of problems have been identified for self-reporting, specifically related to the expertise of those filling out the survey (Salazar and Holbrook, 2004; Mairesse and Mohnen, 2010). Kleinknecht et al. (2002) note that firms do not have exact information about spending on various innovative inputs which explains the high rate of non-response to these questions and thus many firms indicated in the

[48] The Oslo Manual (OECD and Eurostat, 2005) simply defines the reporting unit as “the entity from which the recommended items of data are collected” and states that these may vary from industry to industry and country to country; the ONS (2002) defines the reporting unit as “enterprise – the smallest group of legal units within an enterprise group with a relative degree of autonomy” in line with European System of Accounts (ESA).

comment section of the Dutch CIS 1992 that their figures were “rough estimates”. Salazar and Holbrook (2004) also contend that it is not clear if the respondents definition of R&D and innovation corresponds to that of researchers[49], related to this Godin (2002b) questions the relatively high number of innovative firms as suggested by surveys such as the CIS[50]. Holbrook and Hughes (2001) in this respect suggest to make use of the wording “new and unique to the world/country” rather than just “new to the market” or “significantly improved” to identify actual innovation and provide evidence for the validity of such an approach[51,52]. Similarly Tether (2001) argues that different respondents are likely to have different views, specifically with respect to the definition of “significantly” improved products. In any case the CIS is not able to identify radical innovations as for their assessment hindsight and expert judgement is required (Garcia and Calantone, 2002)[53]. Some of the CIS questions are of even more qualitative nature, asking for the respondent’s subjective evaluation of the importance of sources of information, appropriability methods and objectives of innovation using a Likert type scale.

A further weaknesses of the CIS highlighted by Salazar and Holbrook (2004) is that it does not include information from the public sector. However the public sector as they argue also exhibits innovative activity, specifically when it comes to organizational innovation. Nevertheless the public sector is quite distinct, for instance how would one define the reporting unit here and capture sales figures[54]. Guellec and Mohnen (2001) point out that firms that innovate once within the survey period are treated the same way as those that innovate several times since the questionnaire makes no distinction amongst them, similarly there is no

[49] However even among researchers the exact dimension of innovation are still disputed, Garcia and Calantone (2002), Salazar and Holbrook (2004) for this reason suggest to remove the question on innovative outputs completely.
[50] Though the inclusion of minor, incremental innovations is also put forth as an argument in favour of subject type studies such as the CIS.
[51] The innovations which are not indicated as new to the market can be considered as diffused innovations.
[52] Kleinknecht, Van Montfort and Brouwer (2002) have also noted that the phrasing of the question as “new to the market” is likely to result in small firms over reporting as they are likely to just perceive the region as their market and likewise Mohnen and Mairesse (2010) raise doubts as to the objectivity in distinction between “new to the firm” and “new to the market” by firms.
[53] Also see Archibugi (1988) on discrepancies in perception of what constitutes innovations.
[54] Specifically these accounting issues make it difficult to measure activities in the non-market domain that nonetheless account for a very large part of economic activities, particularly for developed economies, and thus likewise should provide for large potentials of technological advancement.

valuation of the process innovations[55], which makes comparison among countries difficult. Another issue they identify is that the survey period should reflect the "product life cycle" which they believe to be closer to two or one year. A similar discussion by Salazar and Holbrook (2004) though concludes that while for some sectors the product life cycle is shorter than the three years of the survey period for others it is longer. Clearly there are trade-offs among comprehensiveness and capturing the heterogeneous nature of innovative activities which need to be accepted.

The use of strata weights according to industry, size and region is potentially not meaningful when investigating innovation (Teether, 2001). Scaling the sample according to these parameters, while making it representative in terms of the chosen factors, does not imply that it is representative in terms of innovative activity for the underlying population. Furthermore Tether (2001) highlights that counting reporting units in the population and using weights to make the sample representative of these number neglects the true economic significance of each reporting unit which is dependent on their size[56]. For this reason weights have been included in the CIS 6 that are to represent the firms significance in terms of employment, as it turns out these weights however do not represent what they should. They are the same as the previously included firm population weights only multiplied by a different factor. The correct weights could be obtained though from the ARD, here however stratification is not feasible as regional indicators are not reliable. Upon request the ONS could not explain why according to the ARD the bulk of firms were supposedly located in the "South East" while they seem to have reliable information when looking at the data about the population strata reported to underlie the CIS surveys (see for instance table 2.3 below).

2.3. CIS Description, Sampling and Weighting Adjustment

After a round of pilot surveys by the OECD, the Community Innovation Surveys were created and recommendations as to their content and methodology laid out in the

[55] For product innovation there is a question on how much of the sales the innovation has represented.
[56] For correct econometric analysis one does need to use population weights, while for tabulations of nation wide economic activity weighting according to economic significance seems more appropriate.

Oslo Manual (OECD, 1992) by Eurostat together with the Directorate General for Enterprise of the EC. This step established guidelines for OECD firm level innovation surveys facilitating availability and comparability of such data. The UK CIS is voluntary and collected by the ONS (Office of National Statistics) formerly on behalf of the Department of Trade and Industry and since June 2009 on behalf of the Department of Business, Innovation and Skill. The focus of these surveys lies on different sorts of innovative input spending as well as percentage sales of innovative outputs besides some generic information. It also asks respondents about the sources of information for innovation used, cooperation partners and the barriers to innovations experienced. The CIS 4, CIS 5 and CIS 6 contain information about the ownership of reporting units as well as alternative turnover and employment information obtained from the Inter-Departmental Business Register (IDBR).

Table 2.1, IDBR population from which CIS was sampled by sizeband

Sizeband	CIS4	CIS5	CIS6
9-49	145,470	149,141	149,945
50-249	26,061	26,654	25,119
249+	6,452	6,387	4,552
Total	177,983	182,177	179,616

Table 2.2, IDBR population from which CIS was sampled by Region

Region	CIS4	CIS5	CIS6
North East England	5,880	6,055	5,658
North West England	19,475	19,810	19,272
Yorkshire & the Humber	14,808	15,041	14,646
East Midlands	13,072	13,259	12,851
West Midlands	16,042	15,986	15,514
Eastern England	16,446	16,754	16,607
London	25,601	26,055	26,661
South East England	25,064	25,586	25,574
South West England	15,081	16,037	15,749
Wales	6,466	6,886	6,828
Scotland	13,167	13,694	13,467
Northern Ireland	6,881	7,015	6,789
Total	177,983	182,177	179,616

Table 2.3, IDBR population from which CIS was sampled by division

Division	CIS4	CIS5	CIS6
Mining and quarrying	364	265	282
Mfr of food, clothing, wood, paper, publish & print	12,269	11,391	10,182
Mfr of fuels, chemicals, plastic metals & minerals	17,401	16,588	15,456
Mfr of electrical and optical equipments	4,099	3,863	3,483
Mfr of transport equipments	1,667	1,563	1,419
Mfr not elsewhere classified	3,059	2,930	2,589
Electricity, gas & water supply	65	90	91
Construction	17,168	18,413	19,552
Wholesale trade (incl cars & bikes)	25,576	25,748	24,466
Retail trade (excl cars & bikes)	15,515	15,261	15,041
Hotels & restaurants	21,487	23,447	24,224
Transport, storage	7,395	9,097	8,610
Post & Courier activities	1,228	723	517
Telecommunications	1,357	374	553
Financial intermediation	4,073	4,227	4,361
Real estate	5,775	8,382	5,999
Renting of Machinery and Equipment	3,599	3,359	1,993
Computer and Related Activities	6,412	7,686	5,715
R&D on natural sciences & engineering	3,037	849	558
R&D on social sciences & humanities	720	717	54
Architectural and engineering activities	5,771	7,178	4,834
Technical testing and analysis	2,563	415	385
Other business activities	17,384	15,563	28,959
Motion picture and video production		4,048	293
Total	177,983	182,177	179,616

The CIS is sent out to over 28,000 UK reporting units[58,59], with 9 or more employees based on a stratified sample drawn from the IDBR which contains over 170,000 companies. Strata are based on sizeband, sector and region (see tables 2.1 – 2.3 for details). For the period of 2002 to 2004, named the CIS 2005 / CIS 4 a response rate of 58% (16,444) was achieved. The UK CIS for the period of 2004 to 2006, named the CIS 2007 / CIS 5 achieved a response rate of 53% (14,872), while the UK CIS for the period of 2006 to 2008, named CIS 2009 / CIS 6 achieved a response rate of 49% (14,281) (see tables 2.4 – 2.6 for details). The overall response rate shows a downward trend possibly reflecting an increasing concern of firms with

[58] This can be the whole enterprise or part of the enterprise identified by lists of local units, enterprises being defined as "the smallest group of legal units within an enterprise group with a relative degree of autonomy" ONS(2002), they are interchangeably also referred to as reporting unit.
[59] Note that throughout the thesis the term enterprise (reporting) unit is "incorrectly" substituted by firm, organization, company, business, etc.

confidentiality of their data. The variation of response rates within divisions is considerable at times, for instance for the CIS 4 response rate for financial intermediation is 57% and for the CIS 6 it is only 42%. According to the ONS the underlying population from which the sample was drawn has undergone substantial changes (see again table 2.2). As a result of both of these effects the number of observations for specific divisions across surveys has also changed (table 2.6). In a similar way the number of observations available across sizebands has fluctuated (table 2.4). Most prominently the number of observations for the small sizeband has decreased by roughly 10% for the CIS 5 compared to the CIS 4 and by about 20% for the CIS 6 compared to the CIS 4. This is the result of falling response rates among small firms.

Table 2.4, Response rate for CIS by sizeband as % and as observations

	Percentages			Observations		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Sizeband						
9-49	58	52	46	9,098	8,215	7,078
50-249	59	56	53	3,946	3,321	3,693
249+	55	52	54	3,401	3,336	3,510
Total	58	58	49	16,445	14,872	14,281

Table 2.5, Response rate for CIS by region as % and as observations

	Percentages			Observations		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Region						
North East England	58	55	49	950	1,063	959
North West England	58	51	48	1,499	1,285	1,236
Yorkshire & the Humber	58	53	48	1,348	1,239	1,169
East Midlands	59	54	50	1,329	1,237	1,136
West Midlands	59	52	52	1,457	1,251	1,286
Eastern England	59	54	49	1,419	1,312	1,157
London	54	51	49	1,615	1,381	1,519
South East England	59	52	48	1,738	1,366	1,409
South West England	58	54	50	1,361	1,297	1,227
Wales	59	57	49	1,100	1,137	981
Scotland	57	53	49	1,270	1,223	1,184
Northern Ireland	53	54	48	1,359	1,081	1,018
Total	58	58	49	16,445	14,872	14,281

Table 2.6, Response rate for CIS by division as % and as observations

	Percentages			Observations		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Division						
Mining and quarrying	60	47	50	197	53	113
Mfr of food, clothing, wood, paper, publish & print	55	51	49	1,437	1,434	1,091
Mfr of fuels, chemicals, plastic metals & minerals	57	52	49	1,904	2,116	1,278
Mfr of electrical and optical equipments	59	52	52	666	491	583
Mfr of transport equipments	52	50	48	403	260	386
Mfr not elsewhere classified	57	54	48	515	363	435
Electricity, gas & water supply	54	62	53	36	65	62
Construction	56	55	52	1,613	1,028	1,059
Wholesale trade (incl cars & bikes)	59	57	52	1,342	1,325	1,216
Retail trade (excl cars & bikes)	57	52	47	1,547	936	946
Hotels & restaurants	55	47	44	991	877	908
Transport, storage	57	53	51	1,058	1,120	1,050
Post & Courier activities	54	49	47	154	77	152
Telecommunications	61	50	46	178	60	114
Financial intermediation	57	52	42	673	503	536
Real estate	57	55	50	416	618	747
Renting of Machinery and Equipment	60	55	49	284	272	393
Computer and Related Activities	58	50	43	439	517	478
R&D on natural sciences and engineering	65	52	48	207	89	141
R&D on social sciences and humanities	59	50	52	30	34	39
Architectural and engineering activities	67	55	50	436	522	579
Technical testing and analysis	64	54	48	154	49	133
Other business activities	60	59	55	1,765	1,909	1,693
Motion picture and video production		47	44		154	149
Total	58	58	49	16,445	14,872	14,281

The other dataset drawn upon in the thesis, the ARD, nowadays consists of the Annual Business Inquiry (ABI) collected by the ONS, in this case by its Business Data Linking (BDL) branch. Like the CIS it contains Inter Departmental Business Register (IDBR) references through which observations can be linked. The CIS 4 has thus been linked with the ARD 2004, the CIS 5 with the ARD 2006 and the CIS 6 with the ARD 2008[60]. The ARD data is a compulsory census on large businesses and a sample of smaller ones. However it does not include information on firms from Northern Ireland after 2001. It mainly contains information on employment, turnover and capital expenditure as well as indicators of region, ownership country and industrial classification. For those firms not part of the census it still contains information about the region in which they are located, their turnover and employment. While

[60] While samples should have been based on these ARD populations matching was not complete and was improved by "filling" in missing observations with ARD data from previous and subsequent years.

the ARD is also collected at reporting unit level like the CIS, it contains information on employment in individual local units (or plant data).

The industrial classification for the SIC codes used by the Office of National Statistics in the UK are based on i) the character of goods and services produced, ii) the uses to which the goods and services are put, and iii) the inputs, the process, and the technology of production (ONS, 2003)[61]. For intermediate products the "physical composition and stage of fabrication" has the largest weight attached. For "goods with complicated production processes, the end-use, technology and organization of production of the item are often given priority over the physical composition of the goods". The ownership structure and whether activities are "market or non-market" activities has no influence on the classification.

These definitions hint at the complex and difficult nature of applying industrial classifications, specifically in light of underlying heterogeneity of firm characteristics as posited by the evolutionary literature (Nelson and Winter, 1982) and for which evidence is found for instance in Palmberg (2004) and Srholec and Verspagen (2008). The usefulness of industrial classifications for say measuring technological opportunities applied in the literature (among others by Scherer, 1967a; Levin et al., 1985; Geroski, 1990; Cohen and Levinthal, 1989, 1990; Klevorick, Levin, Nelson and Winter, 1995) including this work are thus open to criticism. As Tether and Howells (2004) argue firms with similar industrial classification may have quite different properties in terms of innovative activities and strategies undertaken, citing as an example the different innovative approaches followed by airlines (traditional vs low cost) and that this leads to "evolution" of the sectors themselves. They also conclude that further efforts need to be made to "harmonise" the industrial classifications across countries as attempted by the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations, 2002), to achieve better comparability of data among countries. Beyond the aforementioned heterogeneity Griliches (1992) points out that while one may argue that there is a technological relatedness within SIC

[61] The UK SIC was revised in 2007 (ONS, 2007) however SIC 2003 codes were available for CIS 4, CIS 5 and CIS 6 and have thus been used for comparability

classifications (see table 2.7 for details of the SIC classifications found in the CIS) it is not clear to what extent they exist across different SIC classes. Thus information about potential spillovers across related industries which are distinct according to SIC classification cannot be inferred based on these. Griliches (1992) further points out that diversification makes it even more difficult to apply an appropriate industrial classification to large firms. This is one of the reasons why the CIS is collected at reporting unit level rather than at the firm level.

Table 2.7, Industrial Classifications of enterprises in the CIS4, CIS5 and CIS6

Industry description	Division	SIC
Mining and quarrying	1	10 to 14
Manufacturing of food, clothing, wood, paper, publish & print	2	15 to 22
Manufacturing of fuels, chemicals, plastic metals & minerals	3	23 to 29
Manufacturing of electrical and optical equipments	4	30 to 33
Manufacturing of transport equipments	5	34 to 35
Manufacturing not elsewhere classified	6	36 to 37
Electricity, gas & water supply	7	40 o 41
Construction	8	45
Wholesale trade (incl cars & bikes)	9	50 to 51
Retail trade (excl cars & bikes)	10	52
Hotels & restaurants	11	55
Transport, storage	12	60 to 63
Post & Courier activities	13	64.1
Telecommunications	14	64.2
Financial intermediation	15	65 to 67
Real estate	16	70
Renting of Machinery and Equipment	17	71
Computer and Related Activities	18	72
R&D on natural sciences and engineering	19	73.1
R&D on social sciences and humanities	20	73.2
Architectural and engineering activities	21	74.2
Technical testing and analysis	22	74.3
Other business activities	23	Rest of 74
Motion picture and video production		92.11

Industries with SIC code 73100, 'research and experimental development on natural sciences and engineering' as well as SIC code 73200, 'research and development on social sciences and humanities' have been dropped. The reason is that it is expected that firms in these industries are quite distinct from the rest of the enterprises in terms of their innovative behaviour. As the output of the enterprises in these industries are innovations it is also not clear how they are able to separate their own innovations that is the generation of new services from their outputs which they sell to other firms which are supposed to be innovations[62]. As the tables 2.8 – 2.11 show the firms in this sector are much more innovatively active. While one may argue that this down-weights the overall innovative activity within the economy the contrary is probably true. Including these sectors is more likely to result in double counting as both these firms and the ones that buy the innovation may report it as innovative output. Also for innovative inputs such as R&D spending this criticism is not likely to apply as firms will report it as there extramural R&D spending when they employ the services of firms in the R&D sectors. This is also a reason why extramural R&D spending is included in later analysis as part of firm R&D spending. Overall these two dropped industries represent not more than 1% of the weighted population. The "Motion pictures and video production" industry with SIC code 92100 has also been dropped since it has not been part of the CIS 4 sampling frame and hence this allows for better comparability among the surveys.

Table 2.8, Innovators (product or process) as % weighted sample and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Division						
Mining and quarrying	23.9	19.0	25.8	197	53	113
Mfr of food, clothing, wood, paper, publish & print	36.4	37.8	37.3	1437	1434	1091
Mfr of fuels, chemicals, plastic metals & minerals	40.8	39.1	36.7	1904	2116	1278
Mfr of electrical and optical equipments	60.1	54.1	52.3	666	491	583
Mfr of transport equipments	41.8	38.2	34.0	403	260	386
Mfr not elsewhere classified	44.4	37.7	40.3	515	363	435
Construction	13.5	13.2	15.6	1613	1028	1059
Wholesale trade (incl cars & bikes)	28.7	22.9	25.8	1342	1325	1216
Retail trade (excl cars & bikes)	18.8	21.2	21.8	1547	936	946
Hotels & restaurants	13.4	17.6	21.0	991	877	908
Transport, storage	21.9	19.7	19.3	1058	1120	1050
Post & Courier activities	30.6	33.6	27.8	154	77	152
Telecommunications	50.5	36.6	46.8	178	60	114
Financial intermediation	38.8	29.8	29.8	673	503	536
Real estate	21.4	17.6	17.0	416	618	747
Renting of Machinery and Equipment	25.7	20.5	21.0	284	272	393
Computer and Related Activities	68.9	55.9	53.9	439	517	478
R&D sectors	70.1	43.5	52.7	237	123	180
Architectural and engineering activities	41.5	32.7	37.4	436	522	579
Technical testing and analysis	53.2	40.1	46.6	154	49	133
Other business activities (+ electricity, gas & water)	31.6	23.8	27.6	1801	1974	1755
Total	29.4	26.5	27.8	16445	14718	14132

[62] Freeman and Soete (2009) note that a lot of firms nowadays outsource their innovative activities to reduce their risk exposure, hence these firms' behaviour is likely to be quite atypical in terms of their attitudes toward risk.

Table 2.9, Undertook innovative actives as % of weighted sample and N

Division	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Mining and quarrying	55.6	55.5	55.7	197	53	113
Mfr of food, clothing, wood, paper, publish & print	68.4	78.7	73.9	1437	1434	1091
Mfr of fuels, chemicals, plastic metals & minerals	72.2	79.5	77.8	1904	2116	1278
Mfr of electrical and optical equipments	84.4	89.7	84.6	666	491	583
Mfr of transport equipments	75.3	80.6	72.6	403	260	386
Mfr not elsewhere classified	75.9	79.8	81.3	515	363	435
Construction	45.2	66.1	54.6	1613	1028	1059
Wholesale trade (incl cars & bikes)	54.8	71.1	60.9	1342	1325	1216
Retail trade (excl cars & bikes)	38.0	61.3	57.6	1547	936	946
Hotels & restaurants	40.7	50.1	49.7	991	877	908
Transport, storage	54.2	67.9	57.3	1058	1120	1050
Post & Courier activities	59.5	73.9	53.3	154	77	152
Telecommunications	84.3	74.0	82.0	178	60	114
Financial intermediation	69.9	75.7	68.8	673	503	536
Real estate	48.0	63.2	55.5	416	618	747
Renting of Machinery and Equipment	54.8	67.4	61.5	284	272	393
Computer and Related Activities	81.2	90.2	84.6	439	517	478
R&D sectors	76.1	86.4	89.1	237	123	180
Architectural and engineering activities	72.3	86.0	77.4	436	522	579
Technical testing and analysis	68.3	79.6	74.6	154	49	133
Other business activities (+ electricity, gas & water)	51.2	78.2	66.1	1801	1974	1755
Total	56.1	70.7	64.0	16445	14718	14132

Table 2.10, Spending on innovative activities/sales (as %), weighted

Division	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Mining and quarrying	171.6	6.5	57.4	197	53	113
Mfr of food, clothing, wood, paper, publish & print	6.8	5.2	10.7	1437	1434	1091
Mfr of fuels, chemicals, plastic metals & minerals	8.1	4.9	6.9	1904	2116	1278
Mfr of electrical and optical equipments	9.7	7.3	503.4	666	491	583
Mfr of transport equipments	13.5	8.7	3.8	403	260	386
Mfr not elsewhere classified	44.6	4.2	4.5	515	363	435
Construction	7.2	2.0	7.4	1613	1028	1059
Wholesale trade (incl cars & bikes)	13.9	2.6	2.0	1342	1325	1216
Retail trade (excl cars & bikes)	40.6	4.3	4.5	1547	936	946
Hotels & restaurants	19.6	4.1	29.8	991	877	908
Transport, storage	8.7	3.7	6.3	1058	1120	1050
Post & Courier activities	12.1	2.2	1.9	154	77	152
Telecommunications	33.9	5.3	14.1	178	60	114
Financial intermediation	35.5	5.4	65.2	673	503	536
Real estate	17.0	4.3	10.8	416	618	747
Renting of Machinery and Equipment	6.4	6.9	31.6	284	272	393
Computer and Related Activities	300.3	34.0	509.7	439	517	478
R&D sectors	1443.4	8.8	563.5	237	123	180
Architectural and engineering activities	11.4	6.0	413.9	436	522	579
Technical testing and analysis	13.4	4.7	5.4	154	49	133
Other business activities (+ electricity, gas & water)	19.4	3.7	10.2	1801	1974	1755
Total	51.0	6.0	88.7	16445	14718	14132

Table 2.11, Spending on innovative activities/employees as £1000s, weighted

	Spending			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Division						
Mining and quarrying	11.6	12.4	16.8	197	53	113
Mfr of food, clothing, wood, paper, publish & print	6.8	4.2	5.3	1437	1434	1091
Mfr of fuels, chemicals, plastic metals & minerals	5.3	4.2	3.9	1904	2116	1278
Mfr of electrical and optical equipments	6.4	5.8	9.3	666	491	583
Mfr of transport equipments	5.0	5.3	4.0	403	260	386
Mfr not elsewhere classified	4.9	4.1	4.0	515	363	435
Construction	5.1	1.8	4.3	1613	1028	1059
Wholesale trade (incl cars & bikes)	11.2	4.4	3.8	1342	1325	1216
Retail trade (excl cars & bikes)	11.3	3.6	4.8	1547	936	946
Hotels & restaurants	6.1	1.2	7.9	991	877	908
Transport, storage	6.4	3.1	17.5	1058	1120	1050
Post & Courier activities	5.2	1.2	1.2	154	77	152
Telecommunications	21.8	7.3	16.8	178	60	114
Financial intermediation	9.6	4.6	3.4	673	503	536
Real estate	6.8	2.9	5.1	416	618	747
Renting of Machinery and Equipment	6.9	5.8	21.5	284	272	393
Computer and Related Activities	20.7	10.0	8.5	439	517	478
R&D sectors	24.9	3.6	213.2	237	123	180
Architectural and engineering activities	6.2	3.7	7.4	436	522	579
Technical testing and analysis	6.9	2.9	3.9	154	49	133
Other business activities (+ electricity, gas & water)	5.9	2.0	5.8	1801	1974	1755
Total	8.3	3.8	9.2	16445	14718	14132

The large fluctuations in spending on innovative activities observed across the surveys (table 2.10) are the result of many outliers present in the CIS 4 and the CIS 6, considered as firms that report an R&D spending relative to sales of over 100%[63]. Many of these observations occur in the R&D sectors. However no such outliers can be observed in the CIS 5. Other sectors also show large variations across the survey rounds, this reflects the poor quality of quantitative information available from the CIS (Mohnen and Mairesse, 2010) including the impact of missing observations. The missing observations cannot be identified since the reported spending on innovative activity is reported in the database as either zero or some positive amount. This problem was not an issue in the CIS 3 where firms were clearly asked to indicated whether they had undertaken any or no spending on innovative activities in the last year of the survey period rather then as now for the whole of the survey period.

The CIS sample has been stratified by the ONS to ensure firms from most sizebands, industries and regions are included. To account for this sampling procedure and the

[63] Note that these have not been removed.

survey being voluntary and thus not replied to by all sampled firms there are population weights included in the dataset which are used in calculation of the statistics throughout the thesis. Population weights indicate the probability of firms to be included in the final sample[64] due to the stratification by industry, size band and region that has been used for the sampling. Notably in the CIS 6 these weights are rounded to the next full number and thus weighting here is not as accurate as for the CIS 4 and the CIS 5. As can be seen from the tables 2.12 – 2.14[65] (but also tables 2.1 – 2.3) the actual population is highly skewed towards small sized enterprises which make up slightly over 80% and service industries which make up about two thirds of the total. What can also be noticed from the tabulations is that the weighted sample or what is perceived as underlying population by the ONS has changed considerably in some industries. Most notably for the 'Other Business Activities' where weighted population proportion is thought to have increased almost two-fold in the CIS 6 compared to the CIS 5, but also the 'Technical Testing and Analysis' sector size has considerably decreased after the CIS 4, with some fluctuation in the 'Real estate', 'Computer and Related Activities' and 'Architectural and engineering activities' divisions. A part of these changes are going to be due the results of the natural exit and entry of firms, however it seems implausible that some of the large fluctuations observed can be completely attributed to this effect (see table 2.2 for changes in industry population). These must be down to other reason including possibly changes in classification of industries that firms belong to, though the same industrial classification (SIC 2003) has been used throughout. Another very pronounced effect in terms of the populations the different survey rounds represent is that in the CIS 6 large firms (249+) represent around 2.5% of the population while in the CIS 5 and CIS 4 they represent around 3.6% (table 2.14 also see table 2.1). These differences in composition are thus likely to have an effect on the statistical comparisons across the surveys due to the different weighting applied.

[64] That is those firms that actually responded to the survey.
[65] These tables were computed based on tables 2.1 – 2.3 as well as information from 2.8. The actual results are very similar though. The reason why these are not based on direct information from the data is that the SDS was not willing to clear these tables on the grounds that they could be differenced with tables 2.15 – 2.16 to give cell counts lower then 10 which irrespective of the information content is deemed disclosive.

Table 2.12, Weighted % by region, original weights (excluding R&D sector)

Region	CIS 4	CIS 5	CIS 6
North East England	3.3	3.4	3.2
North West England	10.9	11.1	10.7
Yorkshire & the Humber	8.3	8.4	8.2
East Midlands	7.3	7.4	7.2
West Midlands	9.0	9.0	8.6
Eastern England	9.2	9.3	9.2
London	14.4	12.7	14.8
South East England	14.1	14.1	14.2
South West England	8.5	9.0	8.8
Wales	3.6	3.9	3.8
Scotland	7.4	7.6	7.5
Northern Ireland	3.9	4.0	3.8
Observations	16,208	14,595	13,952

Table 2.13, Weighted % by division, original weights (excluding R&D sector)

Division	CIS 4	CIS 5	CIS 6
Mining and quarrying	0.2	0.2	0.2
Mfr of food, clothing, wood, paper, publish & print	7.0	6.5	5.7
Mfr of fuels, chemicals, plastic metals & minerals	10.0	9.4	8.6
Mfr of electrical and optical equipments	2.4	2.2	1.9
Mfr of transport equipments	1.0	0.9	0.8
Mfr not elsewhere classified	1.8	1.7	1.4
Electricity, gas & water supply	0.0	0.1	0.1
Construction	9.9	10.4	10.9
Wholesale trade (incl cars & bikes)	14.7	14.6	13.7
Retail trade (excl cars & bikes)	8.9	8.6	8.4
Hotels & restaurants	12.3	13.3	13.6
Transport, storage	4.2	5.2	4.8
Post & Courier activities	0.7	0.4	0.3
Telecommunications	0.8	0.2	0.3
Financial intermediation	2.3	2.4	2.4
Real estate	3.3	4.8	3.4
Renting of Machinery and Equipment	2.1	1.9	1.1
Computer and Related Activities	3.7	4.4	3.2
Architectural and engineering activities	3.3	4.1	2.7
Technical testing and analysis	1.5	0.2	0.2
Other business activities	10.0	8.8	16.2
Observations	16,208	14,595	13,952

Table 2.14, Weighted % by sizeband, original weights (excluding R&D sector)

Sizeband	CIS 4	CIS 5	CIS 6
9-49	81.7	81.5	83.5
50-249	14.6	14.9	14.0
249+	3.6	3.6	2.5
Observations	16,208	14,595	13,952

To somewhat correct for these differences and allow for better comparability among surveys, for the CIS 4 and the CIS 6 weights are recalculated based on the population reported to underlie the CIS 5 and those are used for any subsequent analysis (see tables 2.15 – 2.17)[66]. This also rectifies the problem of rounded weights in the CIS 6[67] providing more accurate weights and thus better sample representation particularly of large firms and those in the 'other business activities' division. To calculate weights based on the CIS 5, weights in the CIS 5 are used to extract population sizes for each strata as these are not provided by the ONS along the three relevant dimensions of industry, sizeband and region. Of course this means ignoring changes in the composition of the population but using information from the CIS 5 and thus so to speak the in-between point should make this less dramatic an issue. Not all of the Strata found in the CIS 4 and the CIS 6 could be matched with ones found in the CIS 5 and thus 200 and 96 observations for the CIS 4 and the CIS 6 respectively had to be dropped (see tables 2.15 – 2.17 for results).

Table 2.15, Weighted % by sizeband, CIS 5 weights (excluding R&D sector) and N

	Percentages			Sample sizes		
Sizeband	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
9-49	81.6	81.5	81.6	8,852	8,002	6,782
50-249	14.9	14.9	14.9	3,781	3,291	3,611
249+	3.5	3.6	3.6	3,375	3,302	3,463
Total	100	100	100	16,008	14,595	13,856

[66] In case reclassifications of firms' industry sector occurred this approach is not ideal either.

[67] Upon request the ONS indicated that this is not 'a big issue' and that no more accurate weights would be provided.

Table 2.16, Weighted % by division, CIS 5 weights (excluding R&D sector) and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Division						
Mining and quarrying	0.2	0.2	0.1	152	53	94
Mfr of food, clothing, wood, paper, publish & print	6.5	6.5	6.5	1,437	1,434	1,091
Mfr of fuels, chemicals, plastic metals & minerals	9.4	9.4	9.4	1,904	2,116	1,278
Mfr of electrical and optical equipments	2.2	2.2	2.2	666	491	583
Mfr of transport equipments	0.9	0.9	0.9	399	260	383
Mfr not elsewhere classified	1.7	1.7	1.7	515	363	434
Electricity, gas & water supply	0.0	0.1	0.0	36	65	52
Construction	10.4	10.4	10.4	1,613	1,028	1,059
Wholesale trade (incl cars & bikes)	14.6	14.6	14.6	1,342	1,325	1,216
Retail trade (excl cars & bikes)	8.7	8.6	8.7	1,547	936	946
Hotels & restaurants	13.3	13.3	13.3	991	877	908
Transport, storage	5.2	5.2	5.2	1,058	1,120	1,050
Post & Courier activities	0.4	0.4	0.4	139	77	146
Telecommunications	0.2	0.2	0.2	111	60	85
Financial intermediation	2.4	2.4	2.4	673	503	536
Real estate	4.8	4.8	4.8	416	618	747
Renting of Machinery and Equipment	1.9	1.9	1.9	272	272	388
Computer and Related Activities	4.4	4.4	4.4	439	517	477
Architectural and engineering activities	4.1	4.1	4.1	423	522	572
Technical testing and analysis	0.2	0.2	0.2	110	49	118
Other business activities	8.8	8.8	8.8	1,765	1,909	1,693
Total	100	100	100	16,008	14,595	13,856

Table 2.17, Weighted % by region, CIS 5 weights (excluding R&D sector) and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Region						
North East England	3.4	3.4	3.4	943	1,056	948
North West England	11.1	11.1	11.1	1,443	1,276	1,200
Yorkshire & the Humber	8.4	8.4	8.4	1,323	1,228	1,139
East Midlands	7.4	7.4	7.4	1,291	1,225	1,115
West Midlands	9.0	9.0	9.0	1,411	1,246	1,269
Eastern England	9.3	9.3	9.3	1,384	1,281	1,124
London	12.7	12.7	12.7	1,529	1,260	1,380
South East England	14.1	14.1	14.1	1,687	1,330	1,360
South West England	9.0	9.0	9.0	1,328	1,287	1,199
Wales	3.9	3.9	3.9	1,090	1,128	968
Scotland	7.6	7.6	7.6	1,236	1,204	1,154
Northern Ireland	4.0	4.0	4.0	1,343	1,074	1,000
Total	100	100	100	16,008	14,595	13,856

2.4. Changes across Surveys and related Limitations

In the CIS 4 the definition of an enterprise is given as: "the smallest combination of legal units that is an organisational unit producing goods or services which benefits from a certain autonomy in decision making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more location. An enterprise may be a sole legal unit". All subsequent questions then refer to "your enterprise". In the CIS5 and CIS6 on the other hand questions are phrased as "in this business". At the start of the surveys it is indicated that: "If this enterprise is part of an enterprise group, please answer all further questions only for this enterprise in the UK. Do not include results for subsidiaries or parent enterprises outside of the UK"[68]. The definition of innovation has also been changed. While for the CIS 5 and the CIS 6 the focus is clearly on technological innovation vaguely mentioning wider innovation in the CIS 4 innovation is defined in a more broad sense and it is suggested that innovative activities itself already constitute innovations[69]. On the other hand in the CIS 6 now firms are considered implicitly "innovation active" if they undertake wider forms of innovations which qualifies them to answer to questions about information sources used for innovation, aims of their decision to innovate as well as cooperation partners used for innovation activities. So it would seem appropriate to have retained the definition provided in the CIS 4. Furthermore it is unclear why the overview that is provided to the respondent about what to expect in the survey provided in the CIS 3 is no longer included in the later CIS rounds. It would seem to keep this signpost as well as a statement as to the importance of the data that is being collected would not have harmed the quality of the responses.

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[68] The term "enterprise" is replaced by "business" for the CIS 5 and the CIS 6.

[69] In the CIS 4 respondents are advised that: "Innovation is defined as major changes aimed at enhancing your competitive position, your performance, your know-how or your capabilities for future enhancements. These can be new or significantly improved goods, services or processes for making or providing them. It includes spending on innovation activities, fore example on machinery and equipment, R&D, training, goods and service design or marketing." On the other hand in the CIS 5 and the CIS 6 it is indicated that: "Innovation for the purpose of this survey, is defined as new or significantly improved products (goods or services) and/or the processes used to produce or supply them, that the business has introduced, regardless of their origin. These may be just new to the business or new to the market. Investment for future innovation and changes that the business has introduced at a strategic level (in organisation and practices) are also covered."

References to the time frame of the surveys have seen slight changes. In the CIS 4 it is mentioned at the start that the time period 2002-2004 refers to calendar years this is no longer the case for the CIS 5 and CIS 6 where the exact time frame to the day is specified at the start of each question. This may reflect a realization that respondents for the CIS 4 may have referred to the tax year or their accounting year when filling out the survey forgetting or not reading properly what was specified at the start of the survey. It may indeed be helpful for the accuracy of the quantitative information to allow the use of accounting year information rather than asking respondents to make guesses about calendar year data.

Starting with the CIS 5 the questions on whether the enterprise was part of an enterprise group and whether it has been established later than 2 years prior to the survey time frame has been dropped. In the CIS 6 the question as to what "best defines the main customers" has also been removed. Instead from the CIS 5 on firms were asked to indicate details as to what may have affected large turnover changes such as being a start-up having had a merger or sale of part of the firm. A question set as to what respondents' main business objectives were has been introduced in the CIS 6. This relates to profit, growth in sales or exports and market share in the UK. Such information is certainly useful to account for the previously noted shedding and acquisition of plants by enterprises.

The question about 'innovative activities undertaken' phrasing has also seen changes across the surveys. While in the CIS 4 these were named "innovative activities", in the CIS 5 and the CIS 6 these are termed "innovation related activity" and "innovative related activities" respectively. These are the only implicit definition provided to respondents who are then asked to rate their sources of information used for the above survey specific terms. Furthermore in the CIS 4 and CIS 5 firms that "had no innovation activity" where asked why it has not been possible to innovate, when the former if interpreted as innovative inputs clearly does not exclude the possibility of introducing and innovation, i.e. an output. This is somewhat addressed in the CIS 6 where only firms responding negatively to have not introduced wider forms of innovations or product and process innovations were asked “why it has not been necessary or possible to innovate”[70]. This disconnect between inputs and outputs is a problem of the survey relating to its subject type nature but could be overcome by connecting it to the question of abandoned and ongoing or incomplete activities. The latter question as well as the one on constraints refers to just “innovation activities” (across all surveys). This chaos of terminology leaves the respondent unclear as to what ‘innovation activity’ or similarly named terms refer to. It is likely to lead to different interpretations and thus errors in responses or even may cause omitting to answer.

Another caveat relating to the question about innovative activities is that with the CIS 5 a more detailed breakdown of types of innovative activities undertaken has been introduced. Notably the “acquisition of machinery, equipment and software for innovation” response option has been split into three separate options and the “market introduction of innovations” response option was split into “changes to product or service design”, “market research”, “changes to marketing methods” and “launch advertising”.

Another difference among the surveys is that for the CIS 5 only firms with product or process innovations were asked to respond to the question on the “effects of innovations”[71]. Similarly in the CIS 6 firms that are not innovative are asked to skip the questions regarding ‘effects of innovation’, ‘information sources’ and ‘cooperation partners’. Being innovative has starting with the CIS 6 as per survey design as opposed to verbally (see footnote 55) been defined as those firms that did either introduce technological innovation, non-technological innovations and/or that had incomplete or ongoing innovative activities. While in other countries where the survey is compulsory this sort of qualifier may lead respondents to simply answer no for innovative activities allowing them to skip part of the survey it is hoped that with the UK CIS being voluntary this is not the case.

[70] Again here though note that according to the definition of innovation provided at the start of the CIS 6 wider forms of innovation are not included.

[71] This is the heading it received in the CIS 4, in the CIS 5 this was changed to “determining factors for innovation” and with CIS 6 it was found with other items under the heading “context for innovation”.

In the CIS 6 the question set on the factors important in the decision to innovate was extended by splitting the response option previously phrased as entering new markets and increasing market share into two separate ones. The response option regarding “reducing environmental impacts or improved health and safety” was also split into two. Furthermore in the CIS 6 an option about “replacing outdated products or processes” was added. The question’s wording has also seen changes. While in the CIS 4 it is phrased related to “your product (goods or services) and/or process innovation introduced”, in the CIS 5 and CIS 6 it is related to “your decision to innovate”. This suggests that this question for the CIS 4 refers to innovations introduced during the survey period but potentially initiated previously. What it refers to in CIS 5 and CIS 6 is unclear because a firm can generally not simply “decide to innovate”[72]. What an enterprise can do is to decide to undertake innovative activities with the aim to generate innovation. So the wording of the question here is confusing[73] as firms may not be clear as to whether this question is about the decision to carry out innovative activities or about whether they had actual outputs generated. If it is for the former it is also likely that judgement of the firms as to the innovations effects varies from what the innovation is perceived to have achieved after it is introduced due to the knowledge generated while carrying out innovative activities which influences the perception of the innovation. In this respect it is expected that the CIS 3 by prompting respondents to give a written description of their innovations has led them to be less likely to over report innovative outputs.

In the CIS 6 firms that introduced wider innovations are asked to respond to the question set relating to “effects of innovation”. Though this is in line with the new definition of innovation in the Oslo Manual (OECD, 2005)[74], the question set about “effects of innovation” has not been adjusted to reflect that now potentially firms

[72] If this was just an issue of making a decision every firm would innovate as it only needs to “decide” to do so. The generation of innovation is a random process but dependent on the decision to carry out innovative activities and thus often requiring investments on the part of the firm.

[73] This confusion is aggravated in the CIS 6 by a change in ordering of the questions, while for both CIS 4 and CIS 5 this question comes directly after the question sets regarding product and process innovations introduced during the survey period and only after this question are the firms asked about “innovative activities” such as R&D, both these question sets precede the question in the CIS 6.

[74] Where wider innovations including significant changes to marketing and organisation are now considered innovations by themselves.

with "wider innovation" but no technological innovation respond to this question. The phrasing of the question still refers to "product and process innovation" and also the factors considered important are still the old ones geared towards technological innovation and not relating to marketing or organisational changes. Likewise it is not clear why firms that have not yet introduced an innovation or who abandoned their innovative activities are to respond to this question in the CIS 6[75]. The judgement of the firms that have introduced their innovation is very likely to be different from those firms that are still planning to introduce their innovation or have failed to do so, reflecting the uncertainty involved in innovation as well as the knowledge generation associated with the process.

The question on the importance of appropriation methods for firms' innovations has considerably changed in the CIS 6. Previously phrased as "importance of methods to protect innovation" it now reads "did your enterprise: apply for patent, register industrial design, register a trademark and produce materials eligible for copyright". Thus for the CIS 4 and the CIS 5 this question relates to the competitive environment whereas for the CIS 6 this question refers to actual innovative outputs generated. It would seem useful to have both types of information available in future CIS rounds.

While in the CIS 4 firms were asked about "how important were the following factors as constraints to your innovation activities or influencing a decision not to innovate" this has been rephrased in the CIS 5 to "how important were the following factors as constraints on innovation activities in influencing a decision not to innovate" however in the CIS 6 this has been phrased as "how important were the following factors in constraining innovation activities". So in the CIS 4 this question is relevant to all firms, in the CIS 5 it only applies to firms that did not innovate. Though whether this implies innovative activities or actual innovation in the CIS 5 is again similar to the question on effects of innovation left unclear. For the CIS 6 on the other hand due to the phrasing, firms that did not carry out

[75] This seems to be in response to the criticism about the neglect of firms with "failed" or "ongoing" innovative activities.

innovative activities will not feel they need to respond to this question. Whether this question is useful and in what form will have to be established in the future.

The question about “ongoing” or “abandoned” innovative activities has been rephrased to “incomplete” or “abandoned” starting with the CIS 5. The word “incomplete” seems somewhat inappropriate given the continuous nature of innovative activities. Another point about this question is that a firm may have completed its innovative activities but not yet launched the new product. Again this is a shortcoming of the “snapshot” nature of the survey. Firms for whom this is the case are thus perceived as “failures” in their innovative activity.

The question regarding public support received has not been included in the CIS 5, thus analysis about government support can only be carried out for the CIS 4 and the CIS 6. Both questionnaires ask from what government levels financial support for innovation has been received. While the CIS 4 refers to “central government and devolved administrations” as one government level in the CIS 6 this is changed to “central government” only, thus it can be assumed ‘devolved administrations’ support are now reported under the first option “local and regional authorities”. For the CIS 4 only, businesses that indicated to have received central government support are also asked whether they “did claim a tax credit”. Similarly those reporting the receipt of EU support are also asked whether they participated in the EU’s Framework Programme for R&D. The CIS 3 had the questions on sources of government support split into whether this was in the form of “financial support” or “other participation”. Besides it asked whether firms were involved in any of four major innovation related public programmes but under very general headings (Technology Development, Technology Acquisition, Management Information Programmes and European programmes). Another important change here is the exact definition of financial support, while for the CIS 4 this was explicated as “tax credits or deductions, grants, subsidised loans and loan guarantees.” in the CIS 6 it is “tax credits or deductions, grants, subsidised loans and equity investments”. Thus loan guarantees which do not involve a direct financial flow were excluded and equity investments included. As one of the foremost aims of the CIS is to gauge innovation policy it would seem useful to keep soliciting the sort of information asked for in the CIS 3. This could potentially include quantitative information about support size such as R&D tax credits received.

The CIS 6 has seen considerably rearrangement in terms of the structure. The questions about wider forms of innovation have been moved to the front included among the section ("B") concerning "innovation activity". Overall the CIS 6 through framing the pages and including strange acronyms around the questions which are not relevant to the respondents and a question asking respondents to check answers from previous pages may be less accessible. Specifically moving the question sets with several options towards the end of the survey no longer interspersed with individual simple questions may get respondents "bored" and thus cause them to quit or become less accurate in their responses. However the number of pages has been reduced as a result of this compression.

An important issue that needs to be considered when using survey data are measurement errors. These may occur both for binary outcome variables as a result of incorrect classification as well as for continuous data such as R&D spending figures which as noted in the previous paragraph may not be available directly from company accounts to the respondent or inaccurately reported for some other reason. For the former as well as for the latter changes in the surveys design described within this section are likely to cause different sort of mistakes by respondents and thus measurement errors. As seen in table 2.10 this problem is aggravated when using a fraction of two reported continuous financial variables. Regarding these measurement errors for continuous data the following changes in the survey rounds are likely to have had an impact. In the CIS 4 financial information was to be reported in thousands of pounds (not explicitly specified, only indirectly by allowing the respondents to fill out 7 figures in 7 blocks which had "0" in each of the 3 blocks at the end, providing for a total of 10 figures/blocks). The CIS 5 has seen a notable change in that now firms were clearly told "Please round to the nearest £ thousand" with the last three blocks replaced by a single block which contained ",000". The CIS 6 on the other hand contained 9 blocks only with 3 blocks each clearly separated by a comma, the last three blocks then containing a "0" each. It is possible that respondents in small firms crossed out the last three figures and reported spending to the pound – the OCR software[76] used to read out the survey would not have been able to pick up on this and reported these figures as thousands[77]. Possibly prompted by the clear instructions described above which are contained in the CIS 5 this may not have been the case and explains why the figures of that survey are the lowest and most plausible with the smallest standard deviation. Another change that occurred over the surveys is that while in the CIS 4 respondents are told to provide data based on "management accounting information or using informed estimates" in the CIS 5 and CIS 6 they were prompted to "please ESTIMATE". The same is true for the average number of employees where firms in the CIS 4 were only asked to report rather than "please ESTIMATE" as in CIS 5 and CIS 6 – in part for this reason this information including turnover was taken from the IDBR instead. The aforementioned issues are likely to have led to different measurement errors across the surveys and thus explain the large fluctuations observed across surveys as in table 2.10. Other potential sources for such differences are outliers. Of course a priory there is no particular reason to exclude them unless they are believed to be the result of a clear measurement error. Visual inspection of the distribution of the innovative activities spending intensity (total as well as for each category looked at separately) by total turnover and by employment (looked at an individual industry together with sizeband basis) however did not allow for identification of clear outliers. It has to be noted that the sampling of firms (and original weighting) by industry, region and sizeband has meant that for the CIS 6 the mean firm size is not the same as for CIS 4 and CIS 5 (rows 1 -3 in table 2.18, 2 pages below), more importantly though the variance of the sample is considerably larger than for the CIS 4 and CIS 5 (rows 3 – 6 in table 2.18) this in turn will have caused particularly the continuous financial and employment data to be less comparable across surveys.

[76] Measurement errors may of course also result due to mistakes in transferring the reported results to the CIS dataset by the OCR software. Particularly noteworthy in this respect and related to the seemingly inaccurate continuous information provided in the survey is that the last survey question which is regarding how long respondents took to fill out the survey potentially only allows to respond to a maximum of 99 hours (two number blocks) and 99 minutes (another two number blocks). Nevertheless there is a considerable number of observations where the total number of minutes reported exceeds 6000 minutes. It is unclear how this has come about.

[77] Upon request the ONS did not provide detailed information about whether this may have been the case.

Let's turn to the why potential consequences of measurement errors and remedies are a tricky topic. A major problem with measurement errors is that the process generating the measurement error is of unknown nature. For the factor analysis used in the subsequent chapter for example measurement errors in the binary variables is likely lead to a lower correlation among them, assuming the error is uncorrelated with the observed variable. On the other hand for the nonlinear models in the two chapters thereafter the consequences are less clear. One can distinguish among measurement errors in the dependent variable and measurement errors in the explanatory variables. For linear models measurement errors in the dependent variable just leads to inflated standard errors but results are still consistent. The same is not true for nonlinear models where no generalized results exist as to their effect. Likewise errors in the independent variables cannot be treated for instance as in linear models using instrumental variable techniques as these have generally been shown to be inconsistent (Cameron & Trivedi, 2005). Cameron & Trivedi (2005) note treatment of measurement errors in nonlinear models requires a case by case investigation due to their specific nature and requires very strong a priory assumptions to be made by the researchers. It is likely that for this reason no mention of how to account for measurement errors is made in any papers following similar approaches as the ones taken in this thesis, nevertheless as can be inferred from linear models the consequences are often rather serious. A potential remedy as noted by Cameron & Trivedi (2005) is to obtain multiple responses for the same piece of information (so called replicated data) from individual reporting units, this would involve asking several individuals in the reporting unit to fill out the survey's independently and thus allow for more insights into the underlying error generating process. This task could of course only reasonably be expected to be undertaken by larger firms. On the other hand one could expect measurement errors to be more serious for smaller firms where less effort may have been spent on filling out the surveys due to a lack of resources but also with respect to the accounting data which may not be available in such detail. From the comparison of the means of the variables observed across surveys presented in the next section it becomes clear that the nature of any measurement error generating process are likely to have changed (differences across surveys are often too substantial to be simply the result of changes in general business practices over time) as a result of the changes to the survey design described in this section.

This last paragraph is a more general comment about the survey, specifically the question regarding the product sales intensity. This refers to sales in the last year of the survey time frame, the question itself however relates to product innovations introduced over the whole period of the survey. Thus a respondent who just introduced a very successful innovation but only has done so in the last month of the survey period will appear to have been unsuccessful according to these figures while a firm that has replaced its whole output with a minor innovation at the start of the last year in the survey period will look as to have been extremely successful. Kleinknecht at al. (2002) also argue that sales of innovative products are likely to reflect business cycles and that inter-sectoral comparisons are difficult due to varying product life cycles, thus they recommend that firms should be asked about their product life cycle length. Furthermore Mairesse and Mohnen (2010) note that firms often do not have the appropriate accounting information available in such a way as for them to give a precise answer to these quantitative questions. This is confirmed by the discrepancy of the turnover and employment figures among those reported in the CIS and those obtained from the IDBR (table 2.18). Similar criticisms apply for the question regarding spending on innovative activities in the last year of the survey period.

Table 2.18, Distribution of turnover + standard deviation + observations

variable	weights	Means CIS4	Means CIS5	Means CIS6	Standard Deviations CIS4	Standard Deviations CIS5	Standard Deviations CIS6	Observations CIS4	Observations CIS5	Observations CIS6
turnover start of survey	CIS 5	12674	.	8633	221690	.	159115	15996	0	13849
CIS data	original	12068	.	7271	206834	.	139252	16196	0	13945
	none	34427.83	.	33581.53	337539.4	.	392558.3	16196	0	13945
turnover end of survey	CIS 5	12174	22696	11086	249866	416413	264453	16000	14381	13854
CIS data	original	12510	22696	9400	246250	416413	225013	16200	14381	13950
	none	40187.49	46059.32	42182.47	442975.2	447470.6	656741.8	16200	14381	13950
turnover	CIS 5	14331	12983	14402	491861	258092	276700	16008	14595	13856
ARD data (end of survey)	original	14288	12983	11837	469785	258092	233246	16208	14595	13952
	none	53765.36	44839.01	63999.64	1008552	400524.1	666012.8	16208	14595	13952
employment CIS (000)	CIS 5	64	.	62	585	.	1361	15999	0	13849
at start of survey	original	66	.	54	612	.	1351	16199	0	13945
	none	226	.	251	1293	.	3464	16199	0	13945
employment CIS (000)	CIS 5	69	78	67	613	713	1579	16001	14404	13856
at end of survey	original	71	78	59	630	713	1583	16201	14404	13952
	none	251	270	276	1425	1331	4042	16201	14404	13952
employment ARD (000) at end of survey	CIS 5	72	72	77	608	678	1080	16008	14595	13856
	original	73	72	64	620	678	1022	16208	14595	13952
	none	276	290	362	1458	1624	2839	16208	14595	13952

2.5. Descriptive Tabulations

Table 2.19, Weighted % of sample with the following characteristics and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Foreign ownership (IDBR)	5.1	6.4	6.5	16008	14453	13856
Part of an enterprise group (ARD)	20.9	22.0	21.9	14605	13462	11743
Part of an enterprise group (CIS4)	25.4			15562		
Sold to local/regional markets	83.8	85.1	81.8	15635	13200	11633
Sold to UK	52.8	54.5	54.9	15635	13200	11633
Sold to Europe	23.5	27.7	26.9	15635	13200	11633
Sold to all other countries	16.1	18.5	17.7	15635	13200	11633
Main customer are other businesses	55.1	60.3		16007	14550	
Main customer is the public sector	11.8	15.9		16007	14550	
Main customer are consumers	31.6	33.2		16007	14550	
Established later than 2 years prior to survey period	17.8			15633		
Established during survey period		7.0	9.7		14550	13856
Turnover rose 10% due merger		3.9	6.2		14550	13856
Turnover decreased 10% due sale		4.8	7.7		14550	13856

Table 2.20, Weighted % of employee types + observations + standard deviations

	Means (standard deviations)			Observations		
variable	CIS4	CIS5	CIS6	CIS4	CIS5	CIS6
science & engineering degree (%)	5.8	5.8	4.2	16002	12190	13845
	(29.9)	(15.7)	(13.1)			
other degree (%)	7.4	11.5	6.3	16001	12876	13847
	(25.3)	(23.8)	(16.0)			

Let's first take a look at the general characteristics of the firms contained in the CIS 4, 5 and 6 (table 2.19). The reader is reminded that all figures referred to represent weighted numbers even if this may not always be entirely clear from the wording of the table titles. Between 5 and 7 % of the firms in the weighted samples were under foreign ownership. About a quarter of the weighted respondents are members of an enterprise group according to the CIS 4[78], while the ARD puts this figure at just slightly above a fifth for the three survey rounds. Over 80% sell within their regional market and over 50% within the UK, while only around a quarter do export to European countries and roughly a sixth to even further markets. The enterprises' main customers are around 60% other businesses, roughly a seventh of

[78] This question was no longer contained in later survey rounds.

the enterprises have the public sector as their main customer and around a third is mainly selling to consumers. The percentage of working population presented in the next table (2.20) does not seem particularly reliable given that that the percentage of graduates is over 25% in the UK[79].

Table 2.21, Product innovators as % of weighted sample and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Product innovation	24.3	23.3	24.4	16008	14595	13856
Goods innovation	15.0	14.6	15.2	16008	14595	13856
Services innovation	16.1	17.9	17.6	16008	14595	13856
of which (N total)				4610	3851	3748
By enterprise (group)	66.0	74.1	75.1	4609	3720	3748
Together with others	21.8	61.3	39.7	4609	3720	3748
By others	11.4	12.7	24.9	4609	3720	3748
New to market	55.8	49.5	49.0	4604	3798	3420
New to enterprise	82.0	76.5	78.6	4604	3798	3420
% sales new to market	10.6	7.4	7.5	4609	3851	3748
standard deviation	20.4	15.3	16.4			
% sales new to the enterprise	14.1	12.4	11.5	4609	3851	3748
standard deviation	21.3	19.4	18.5			
% sales significantly improved	15.0	14.0	14.3	4609	3851	3748
standard deviation	21.6	20.9	20.8			
% total sales of above	39.7	33.7	33.3	4609	3851	3748
standard deviation	33.7	32.0	32.5			
% sales unchanged	57.3	59.4	51.8	4609	3851	3748
standard deviation	34.5	34.7	36.4			

In the Oslo Manual (OECD and Eurostat, 1997) which was used to draw up the CIS, technological product innovation is defined as: "the implementation / commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer". There are roughly equal proportions of the weighted sample that introduce service and goods innovation, about a sixth of the weighted sample (table 2.21). As the weighted proportion of firms that introduced both is around a quarter this indicates a considerable overlap with about 10% of the firms in the population having

[79] http://www.ons.gov.uk/ons/rel/lmac/graduates-in-the-labour-market/2012/chd5-graduates-across-the-uk.xls

introduced both goods and service innovations. This confirms the notion that the distinction between services and manufacturing is blurred if a considerable part of the firms indicates to have innovated in both services and manufacturing. Roughly two thirds of these innovations were generated by the enterprise itself according to the CIS 4 but according to the CIS 5 and the CIS 6 these were around three quarter. Similarly there is substantial disagreement in the percentages of the product innovations developed ‘mainly by your enterprise together with other enterprises or institutions’, also the totals do not add up to 100% while it is clearly specified that firms should only tick the most appropriate of the three. This was no longer the case for the CIS 6. Roughly half of those enterprises that introduced product innovations during the survey period also had at least one product innovation that they deemed new to the market, roughly four fifth think that at least one of their innovations already existed in the market. For firms that introduced product innovations during the survey period between 50 and 60% of their sales in the last year of the survey period consisted of old products. Between 14 and 15% consisted of ‘significantly improved’ and a slightly lower amount of ‘new to the enterprise but not new to the market’ products respectively. The remaining sales which were between 7 and 11%, consisted of ‘new to the market’ sales[80].

Table 2.22, Process innovators as % of weighted sample and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Process innovation	15.0	11.5	12.5	16008	14595	13856
of which (N total)				3179	2232	2059
By enterprise (group)	61.9	62.2	61.9	3179	2202	2059
Together with others	26.5	25.0	26.5	3179	2203	2059
By others	9.1	12.8	9.1	3179	2202	2059
New to the industry	29.9	24.9	29.9	3172	2203	1958

Process innovations in the Oslo Manual (OECD and Eurostat, 1997) are defined as: “the implementation / adoption of a new or significantly improved production or delivery method.”. Between 12 and 15% of the weighted respondents report to have introduced a process innovation (table 2.22). Of these around 62% were generated

[80] The totals unfortunately do not add up to a 100% indicating poor efforts of at least some of the respondents in filling out the survey accurately. For the CIS 6 this is most pronounced where the total only adds up to 80%.

within the enterprise. Between 25 and 27% was developed together with other enterprises and the remainder which was between 9 and 13% outside the enterprise. Of those firms reporting process innovations between 25 and 30% indicated that these were new to the industry.[81] This figure is relatively small compared to the weighted percentage of firms indicating that at least one of their product innovations was new to the market which was between 49 and 56%. The reason why this is somewhat odd is that product innovations are a lot more visible to competitors, this should imply that they can be more easily copied but also that other firms are more likely to be aware of them. As has been argued while outputs through which firms compete are quite similar the diversification and exact activities undertaken by firms are a lot more heterogeneous (see for instance Penrose, 1959). Thus one would expect respondents to be less likely to class their product innovations as new to the market then is the case for process innovations. This may reflect a shortcoming in the design of the survey. The question does not ask firms to specify how many product and process innovations they actually introduced. Now if those firms that introduced product innovations did so a lot more often than those firms introducing process innovations then the figures do not necessarily imply that actually a larger percentage of the product innovations were new to the industry than for process innovations. Another aspect also relating to the design of the survey that may be able to explain the differences is that for product innovations the question refers to “new to the market” whereas for process innovations it refers to “new to the industry”. While the respondents are likely to define their output so that it is distinct in a way that it is new to the consumer and thus can be defined as “new to the market” they may be aware that within their industry, that is among the other firms the product (or in this case process) is not necessarily perceived as “new”. So this is an area that could be improved, appropriate phrasing of the question about innovations introduced and including information on the number of innovations.

The question on innovation related activities undertaken includes innovative inputs beyond just standard R&D, as specified in the Oslo Manual (OECD and Eurostat, 2005) these are considered to include for instance innovation related training and

[81] For process innovations the totals did add up roughly to 100%.

marketing. The largest weighted share of firms was involved in the ‘acquisition of machinery, equipment and software’, between 47 and 61% (table 2.23). This share and same goes for the share of the ‘market introduction of innovations’ has seen a considerable fluctuation across the surveys in the weighted percentage of firms undertaking it[82]. The spending on ‘market introduction of innovation’ together with ‘training’ and ‘intramural (in-house) R&D’ hold the second place here in terms of the weighted percentage of enterprises that engages in it. The high positive response rate for ‘training’ suggests that possibly respondents did not properly read or understand this subpart of the question. It is unlikely that a larger percentage of the firms train their staff for innovation then the proportion of firms undertaking R&D. However much of the training for staff is likely to involve elements of innovation, that is adapting workers skills to latest developments in the industry. Overall between 55 and 70% of the enterprises claim to have undertaken some innovative activities during the survey period. The differences in the figures among the survey rounds can be attributed to the increase in weighted percentage of firms reporting spending on ‘acquisition of machinery, equipment and software’ as well as ‘market introduction of innovations’. Training figures though have dropped from roughly over a third to somewhat over a quarter for the CIS6.

[82] Being highest in the CIS 5 is possibly due to the wording being “acquisition of machinery, equipment and software” where the addition “for innovation” present in the CIS 4 and the CIS 6 has been dropped.

Table 2.23, Weighted % of sample reporting (for whole survey period)

		CIS 4	CIS 5	CIS 6
	N	15577	13140	11449
Intramural (in-house) R&D		25.3	27.4	32.4
Acquisition of R&D (extramural R&D)		9.4	10.5	10.6
Acquisition of machinery, equipment and software		41.7	61.2	50.1
-Advanced machinery			19.5	15.9
-Computer hardware			52.0	38.3
-Computer software			53.7	42.3
Acquisition of external knowledge		12.0	13.9	12.0
Training		36.3	35.8	26.6
All forms of Design		14.4	16.7	19.9
Market introduction of innovations		21.8	37.1	36.3
-Changes to product or service design			21.5	22.4
-Market research			18.3	15.3
-Changes to marketing methods			20.8	20.4
-Launch advertising			19.1	18.0
Total		56.1	70.5	63.6

Table 2.24, Weighted % of sample reporting (in the last year of survey)

		CIS 4 2004	CIS 5 2006	CIS 6 2008
	N	16208	14595	13952
Intramural (in-house) R&D		20.0	18.6	20.3
Acquisition of R&D (extramural R&D)		7.1	7.4	6.8
Acquisition of machinery, equipment and software		35.5	43.8	33.5
Acquisition of external knowledge		9.1	9.2	8.2
Training		29.5	26.1	15.9
All forms of Design		10.7	10.3	11.8
Market introduction of innovations		18.4	24.7	14.5
Total		48.7	54.8	43.6

Comparing the percentage of firms that reported spending on innovative activities in the last year of the survey period (table 2.24) these are as expected smaller but not by much compared to those that have reported to have had innovative activities over the whole of the survey period (three years). This can be interpreted as further evidence for the persistence of innovative activities, which means the gravity of a lack of causality among input and output variables for the subsequent cross-sectional analysis is less pronounced. Here again though the differences in the reported figures among the survey rounds for the different individual categories are quite large. For those firms only that reported a positive innovative expenditure in the last year in a particular category (table 2.24) the spending intensity per employee was highest on 'machinery, equipment and software' and 'market introduction of innovations'. The third highest spending category was 'intramural (in-house) R&D'. That a similar proportion of firms carried out 'intramural (in-house) R&D' as those which were involved with 'market introduction of innovations' (see tables 2.23 and 2.24) and the spending intensities among these activities were comparable (see table 2.25)[83] highlights the important role of marketing for innovation an area which for instance Bloch (2007) argues to have been neglected by scholars of innovation. The large figures for spending on 'acquisition of machinery, equipment and software' also confirm the important role of rent spillovers through acquisition of knowledge embedded in capital goods.

Table 2.25, Weighted £1000s spending / employment (if > 0) and N

		Spending			Positive responses		
		CIS 4 2004	CIS 5 2006	CIS 6 2008	CIS 4 2004	CIS 5 2006	CIS 6 2008
Intramural (in-house) R&D		2.9	2.2	1.4	3990	3393	3274
	standard deviation	8.7	6.0	7.2			
Acquisition of R&D (extramural R&D)		1.7	1.0	3.7	1447	1337	1148
	standard deviation	6.2	3.5	5.6			
Acquisition of machinery, equipment and software		5.7	2.2	3.6	6334	7017	4810
	standard deviation	50.5	8.9	28.1			
Acquisition of external knowledge		1.3	0.6	2.0	1674	1473	1191
	standard deviation	8.3	1.8	39.4			
Training		1.2	0.8	1.5	5417	4419	2486
	standard deviation	8.7	4.0	69.4			
All forms of Design		1.3	1.4	1.3	2139	1808	1823
	standard deviation	7.7	2.3	5.8			
Market introduction of innovations		3.5	3.8	6.3	3356	4026	2298
	standard deviation	25.1	7.4	10.0			
Total		8.1	3.8	6.3	8625	8764	6423
	standard deviation	53.4	11.5	62.7			

[83] A table with spending intensity by sales was not cleared by the SDS because differencing between this and table 2.23 would have provided cell counts of less then 10. However from table 2.10 it can be seen that these figures also show considerable fluctuations across surveys.

Table 2.26, Weighted % of sample that indicate and N

	CIS 4	CIS 5	CIS 6	Positive responses CIS 4	CIS 5	CIS 6
Respondents	15,514	13,013	11,822			
ongoing or abandoned innovative activities	9.3	11.1	8.4			
-abandoned		6.2	4.1			
-incomplete		9.1	6.5			
Respondents	15,577	13,140	11,908			
carried out innovative activity such as R&D	56.1	70.5	63.8	9,602	9,918	7,966
Respondents	16,208	14,595	13,952			
introduced technological innovation (TI)	29.2	26.3	27.6	5,677	4,464	4,285
TI or had innovative activity	56.1	64.0	58.4	10,020	10,148	8,455
TI or had abandoned & ongoing activities	31.0	28.8	28.9	6,016	4,904	4,484
TI or had innovative activity or had abandoned & ongoing activities	56.4	64.2	58.5	10,063	10,172	8,464
innovators as defined in CIS 6 (technological, nontechnological & abandoned)	43.1	42.5	38.1	8,248	7,239	6,026
innovators as defined in CIS 6 + those with innovative activity	60.1	66.7	60.8	10,775	10,623	8,894
no innovative activity (% of respondents)	58.5	78.0	55.9	8,575	10,398	7,089
-due prior innovations	32.5	24.7	26.8			
-due market conditions	45.8	48.8	47.5			
-due factors constraining innovation	27.1	22.5	26.4			
-one of the above	65.6	71.0	71.9			

Table 2.27, Weighted % of sample that indicate and N

	CIS 4	CIS 5	CIS 6
Innovative activity (did not responded to one of q2011, q2022, q2030)			
carried out innovative activity (q13xx)	91.6	97.9	86.4
no response to whether innovative activity was undertaken (q13xx)	0.5	1.7	11.2
introduced technological innovation (TI)	66.8	67.0	62.4
TI or had innovative activity	95.2	97.1	83.9
TI or had abandoned & ongoing activities	69.7	73.1	65.3
TI or had innovative activity or had abandoned & ongoing activities	95.4	97.2	84.0
innovators as defined in CIS 6 (technological, nontechnological& abandoned)	81.3	85.4	87.8
innovators as defined in CIS 6 + those with innovative activity	96.0	97.5	90.3
No Innovative activity (responded to one of q2011, q2022, q2030)			
carried out innovative activity (q13xx)	33.2	65.2	46.4
no response to whether innovative activity was undertaken (q13xx)	6.9	13.3	18.0
introduced technological innovation (TI)	6.8	15.9	0.0
TI or had innovative activity	32.1	58.4	38.1
TI or had abandoned & ongoing activities	8.1	17.7	0.0
TI or had innovative activity or had abandoned & ongoing activities	32.5	58.6	38.1
innovators as defined in CIS 6 (technological, nontechnological& abandoned)	23.8	35.2	0.0
innovators as defined in CIS 6 + those with innovative activity	40.2	62.8	38.1

The next question under scrutiny is regarding whether firms had 'ongoing or abandoned innovation activities' (table 2.26). Of those enterprises that replied to this question roughly 10% indicated to have had 'ongoing or abandoned innovative activities' during the survey period. The relatively small percentage of firms that had abandoned innovative activities at roughly 5% can be interpreted as further evidence for the persistence of innovative activities. The figures presented in the bottom part of table 2.26 are the proportion of enterprises that indicated to have 'no innovative activity'. These were between 56 and 78% of the enterprises. For those with 'no innovative activity' the most important factor was 'due market conditions' mentioned by somewhat less than half, the other two factors 'no need due prior innovations' and 'due factors constraining innovation' were mentioned by around a quarter of the enterprises. A considerably part of the proportion of firms that actually had carried out innovative activities such as R&D spending which is between 56 and 71% must have responded positively to having 'no innovative activity' as the total percentage of these two figures adds up to more than 100%. Likewise for alternative definitions of 'innovation activities' (found in the middle of table 2.26) the percentages added to those who reported 'no innovation activities' also do not sum to 100%. There is hence no consensus on what the term "innovation activities" for the CIS 4 or "innovation related activities" for the CIS 5 and the CIS 6 refers to, that is whether it is the introduction of innovations or the use of innovative inputs. This underlines the previous criticism about inconsistency in both explicit and implicit definition of innovation across surveys. It is particularly problematic for the reply of firms to questions related to the 'information sources for innovation activities' as well as 'barriers to innovation activities'. More details of this issue can be seen in the table 2.27. Here the overlap between the various definitions of "innovative activities" and those firms responding to the question about "reasons for not undertaking innovative activity" versus those firms not responding to it are presented. The smallest percentage of firms classified as innovators or innovatively active to respond to why they had "no innovative activity" is obtained when looking at firms with technological innovations only, which is between 7 and 16%[84]. On the other hand the largest percentage of firms

[84] For the CIS 6 this was 0% as the questionnaires structure clearly guided respondents that where considered innovation active according to CIS 6 definition to skip this question.

not responding to the reasons why they had “no innovative activity” is only obtained when applying the widest definition of innovation active (that is the bottom row in table 2.26).

Let’s look at the response rates to the next three question sets that for the CIS 6 are only answered by a subset of the respondents. These are questions about the ‘effects of innovation’, ‘sources of information’ and ‘cooperation partners’ used.

As described in the previous section the question set regarding the effects of innovation has seen a change in phrasing after the CIS 4. Whereas in the CIS 4 it is directed towards results of ‘innovations introduced’ during the survey period[85] in the CIS 5 and the CIS 6 it is phrased to be about the reasons for ‘trying to innovate’ during the survey period[86]. What firms think the innovation is worth after its introduction and what they think it to be useful for before is not the same and thus difficult to compare. The answer set was extended by introducing extra options as well as subdividing questions in the CIS 6 as can be seen in tables 2.28 - 2.30. In the CIS 4 all enterprises were asked to respond to this question, in the CIS 5 only those that “undertook any product or process innovation during the survey period”[87] and in the CIS 6 those that were deemed “innovation active”[88]. For the datasets to be somewhat comparable the proportions have been calculated for firms that introduced product and process innovation during the survey period (table 2.28). This however meant dropping around 1000 observations for the CIS5, these would plausibly be firms that had abandoned or ongoing activities, however including these (table 2.29) only increased the sample of the CIS 5 by 150 respondents. Then the same results again are presented including all of the positive responses to this question set in the CIS 5 (table 2.30). From the aforementioned tables the most important effect of innovation is ‘improved quality of goods or services’, followed by ‘increased value added’ and ‘increased range of goods or services’. The least

[85] “How important were each of the following effect of your product and/or process innovations introduced?”

[86] “How important were each of the following factors in your decision to innovate (product(s)) and/or process(es))” in the CIS 5 and “… innovate goods or services and/or process(es)?” in the CIS 6.

[87] This was checked in a qualifier question before the question set, those answering in the negative were asked to skip this question set.

[88] Defined as those with technological or wider innovation or those with abandoned or ongoing innovative activities, again like in the CIS 6 all other firms were asked to skip this question set.

important factor to enterprises is 'reducing environmental impacts or improved health and safety'.

Table 2.28, Effects of innovation rated as important (medium, high)

Weighted % of firms with innovative outputs (product or process)

	CIS4	CIS5	CIS6
N	5669	2890	3755
Increased range of goods or services	74.1	81.1	86.1
Entered new mkts & increase mkt share	68.6	81.4	83.5
Entered new mkts			70.8
Increase mkt share			75.1
Improving quality of goods or services	82.9	87.7	93.6
Improved flexibility of production or service provision	63.6	66.7	70.7
Increased capacity for production or service provision	58.1	62.1	63.1
Reduced costs per unit produced or provided	53.7	62.6	68.5
Reduced environmental impacts or improved health & safety	41.3	52.1	63.9
Reducing environmental impact			59.1
Improved health & safety			54.9
Met regulatory requirements	52.8	56.0	64.4
Increased value added	75.2	80.7	83.1
Replacing outdated products or processes			63.5
Total	95.8	95.8	99.4

Table 2.29, Effects of innovation rated as important (medium, high)

Weighted % of firms with innovative outputs or ongoing/abandoned activities

	CIS4	CIS5	CIS6
N	6000	3032	3944
Increased range of goods or services	72.3	80.2	85.2
Entered new mkts & increase mkt share	67.5	80.8	83.1
Entered new mkts			70.7
Increase mkt share			74.7
Improving quality of goods or services	81.7	87.3	92.9
Improved flexibility of production or service provision	62.6	66.5	70.2
Increased capacity for production or service provision	57.1	61.9	62.7
Reduced costs per unit produced or provided	53.6	62.6	67.8
Reduced environmental impacts or improved health & safety	41.8	51.8	63.6
Reducing environmental impact			58.7
Improved health & safety			54.6
Met regulatory requirements	52.9	55.4	64.1
Increased value added	74.1	80.4	82.3
Replacing outdated products or processes			63.2
Total	94.9	95.6	99.2

Table 2.30, Effects of innovation rated as important (medium, high)

Weighted % of firms with innovative outputs or ongoing / abandoned and all from CIS 5 responding to this question set

	CIS4	CIS5	CIS6
N	6000	4074	3944
Increased range of goods or services	72.3	66.4	85.2
Entered new mkts & increased mkt share	67.5	66.2	83.1
Entered new mkts			70.7
Increased mkt share			74.7
Improving quality of goods or services	81.7	75.1	92.9
Improved flexibility of production or service provision	62.6	56.0	70.2
Increased capacity for production or service provision	57.1	51.6	62.7
Reduced costs per unit produced or provided	53.6	52.2	67.8
Reduced environmental impacts or improved health & safety	41.8	46.0	63.6
Reducing environmental impact			58.7
Improved health & safety			54.6
Met regulatory requirements	52.9	50.1	64.1
Increased value added	74.1	67.9	82.3
Replacing outdated products or processes			63.2
Total	94.9	85.4	99.2

For the following question sets on 'sources of information used' and 'cooperation partners' similar to the one on 'effects of innovation' results are only presented for firms that have introduced technological innovation or had abandoned or ongoing innovative activities (table 2.31). This is done to make the figures more comparable across the datasets, where in the CIS 6 only firms with technological, non-technological or abandoned and ongoing activities were asked to respond to these questions. Though in the CIS 4 and the CIS 5 all respondents were asked these questions the implicit definition of innovation did not yet include wider forms of innovation[89]. Also note that for the question set regarding 'cooperation partners used' in the CIS 5 and the CIS 6 one cannot distinguish if this question was not responded to or whether firms did not have cooperation partners[90]. Hence one can expect the actual figures to be somewhat higher due to some non-respondents being counted as not having had used cooperation partners when they actually did so.

[89] Since wider forms of innovation were only mentioned at the end of the survey.

[90] For the CIS 4 this was still possible as at the start firms were asked whether they had undertaken any cooperation at all, if so they were asked to complete the question on cooperation activities.

Table 2.31, Weighted % of sample rating information sources as important (medium to high), innovation active enterprises only

	CIS 4	CIS 5	CIS 6
N	8243	7041	4960
Internal	72.0	65.9	81.5
Suppliers	65.8	62.8	65.6
Customers	73.8	73.6	83.9
Competitors	51.1	53.4	61.3
Specialized	22.1	19.6	22.6
HE	10.1	11.0	12.1
Public	10.2	10.4	14.0
Events	36.4	34.2	35.2
Publications	32.5	26.1	23.9
Associations	36.4	33.3	37.4
Standards	39.4	37.9	44.0
Total	90.5	87.9	95.2

The most important sources of information for innovative activities (see table 2.31) are from 'within the firm' and 'customers'. Next in terms of importance are 'suppliers' and 'competitors' to a lesser degree. Notably 'higher education institutions' and 'public research institutions' were only rated as important by between 10 and 14% of the weighted sample. Around 90% of the firms have found at least one source of information for their innovative activities to be important which suggests that there are possibly other information sources not covered by the survey if one assumes that innovations are related to knowledge generation.

Turning to co-operation partners used by firms (for "innovation activities" in the CIS 6 only) presented in table 2.32. Cooperation partners that were mentioned the most by respondents are 'suppliers' and 'customers'. The next most frequently used cooperation partners were 'enterprises within the group'. Notably the least weighted proportion of respondents indicated to have used 'universities or other higher education institutions' and 'government or public research institutes' as cooperation partners. There is considerable discrepancy between the CIS 4 and the CIS5 figures relative to the CIS 6 figures. Partly these could be attributed to the change in wording of the question, while previously this referred to "cooperation partners" thus suggesting more formal ties, in the CIS 6 firms were simply asked if they did "co-operate on any innovation activities" and thus the firms may have interpreted this to include informal ties.[91]

Table 2.32, Weighted % of sample with innovative activities cooperating with

		CIS 4	CIS 5	CIS 6
	N	8248	7239	6026
Other enterprises within the enterprise group		12.0	10.9	29.6
Suppliers of equipment, materials, services, or software		18.2	13.6	39.6
Clients or customers		17.3	13.6	45.2
Competitors or other enterprises in the industry		9.9	7.3	19.5
Consultant, commercial labs, or private R&D institutes		10.1	7.3	17.9
Universities or other higher education institutions		7.4	5.9	14.3
Government or public research institutes		6.8	4.8	13.0
Local cooperation		14.8	11.1	31.8
National cooperation		16.8	14.4	38.8
European cooperation		8.2	6.6	14.1
International (excluding Europe) cooperation		6.4	5.5	16.2
Total		23.9	19.8	59.7

Table 2.33, Weighted % rating innovation barriers as important (medium – high)

		CIS 4	CIS 5	CIS 6
	N	15506	13149	12849
Economic risk		32.5	22.9	38.7
Innovation cost		34.1	25.5	38.1
Finance cost		30.3	24.3	36.7
Finance availability		24.7	19.3	32.6
Lack of personnel		26.7	21.6	24.5
Lack of technology info		15.6	11.4	15.5
Lack of market info		16.0	12.2	15.9
Incumbents market power		26.0	19.4	26.1
Uncertain demand		25.9	19.8	28.2
Meet UK regulations		25.4	18.3	19.2
Meet EU regulations		21.7	15.3	16.1
Total		57.7	46.4	60.6

In the CIS 4 businesses are asked to assess "constraints to your innovation activities or influencing a decision not to innovate" however the CIS 5 only refers to "constraints on innovation activities in influencing a decision not to innovate" while the CIS 6 asks about "factors in constraining innovation activities". This will at least

[91] Though given that the term "innovative activities" was not included previously one may actually have expected the figure to fall, ie firms may have reported cooperation on other activities such as distribution or production.

in part explain the differences across the surveys observed in table 2.33. The CIS 5 figures being lower by about 10% for each factor mentioned, while the CIS 6 figures are in parts a bit higher. This suggests that barriers only become apparent once innovative activities are carried out as the knowledge to generate them is processed. The most important barriers mentioned were ‘costs’ and ‘risks’. The least important barriers to innovation were ‘lack of technological and market information’.

Table 2.34, Weighted % rating appropriation as important (medium-high) for CIS 6 only registered the following

		CIS 4	CIS 5	CIS 6
	N	15485	12782	11486
Design		9.4	13.1	1.4
Trademarks		13.1	17.3	6.0
Patents		9.0	11.2	3.4
Confidentiality		21.0	27.6	
Copyright		11.4	15.1	6.3
Secrecy		19.3	22.0	
Complexity		14.3	15.6	
Leadtime		21.1	25.5	
Total		34.2	41.2	11.2

Over a third of the weighted sample found protection methods to be significant for their innovations. The most important protection methods (see table 2.34) were ‘confidentiality’, ‘secrecy’ and ‘leadtime’ advantage. Formal protection methods such as ‘patents’ and ‘design’ were considered the least important protection methods. For the CIS 6 this question refers to actual innovative outputs generated by the businesses and thus the responses are not directly comparable.

Looking at table 2.35, around a third of the proportion of enterprises mentioned to have used a specific ‘wider form of innovation’. Use of ‘new or significantly changes marketing concepts and strategies’ as well as ‘organisational structures’ were mentioned most frequently, while less firms innovated in ‘corporate strategy’ and ‘management techniques’.

Table 2.35, Weighted % with wider innovation

		CIS4	CIS5	CIS6
	N	15503	13114	11902
Corporate strategy		16.1	16.9	14.4
Management techniques		13.4	13.6	11.8
Organisational structure		16.7	22.0	18.8
Marketing concepts or strategies		19.4	20.2	18.0
any		32.4	35.1	31.0

As noted in the previous section the differences in these means across surveys may for one be the result of different measurement errors resulting from the changes in the survey design described in this and the previous section. They may also be the result of heterogeneity of firm activities implying that the use of the law of large numbers and thus regression analysis is less justifiable. Also as noted the sample in its composition despite the use of stratification and corresponding weighting may not be representative (as seen in table 2.18 it certainly is not in terms of firms size when comparing CIS 4 and CIS 5 against CIS 6), there is also a considerably lower response rate in the CIS 6 that may have had an effect (tables 2.4 – 2.6).

However looking at table 2.35 with the evolution of the major activities using different weights, ie the original, the CIS 5 adjusted and no weights the following trends seem to exist across the surveys. Product innovation is fairly constant over the surveys while process innovation is lowest for the CIS 5 and somewhat higher for the CIS 6 (the later could be a result of the sample being skewed towards larger firms in the CIS 6). In terms of innovation inputs (active – proportion of firms that report to have spent on these) the CIS 4 has the lowest percentage of firms reporting such activities over the whole survey period with the highest being observed for the CIS 5, however it needs to be kept in mind for these figures that there is a considerably larger number of missing observations for the CIS 5 and CIS 6 compared to the CIS 4. Again what becomes clear from this discussion is that the representativeness of the surveys is questionable.

Table 2.36, Trends of Innovativeness Weighted % + observations

variable	weights	Means			Observations		
		CIS4	CIS5	CIS6	CIS4	CIS5	CIS6
product innovators (%)	CIS 5	24	23	24	16008	14595	13856
	original	25	23	24	16208	14595	13952
	none	29	26	27	16208	14595	13952
process innovators (%)	CIS 5	15	11	13	16008	14595	13856
	original	15	11	13	16208	14595	13952
	none	20	15	15	16208	14595	13952
innovators (%)	CIS 5	29	26	28	16008	14595	13856
	original	30	26	27	16208	14595	13952
	none	35	31	31	16208	14595	13952
innovation active (%)	CIS 5	56	71	64	15381	13140	11836
	original	57	71	63	15577	13140	11908
	none	62	75	67	15577	13140	11908
innovation active last year (%)	CIS 5	48	55	44	16008	14595	13856
	original	49	55	43	16208	14595	13952
	none	54	60	46	16208	14595	13952

2.6. Conclusion

This chapter has pointed out that the CIS was born due to criticism of simplistic measurement of innovation through R&D spending and patent numbers providing scholars with a much richer set of information about innovative activities and spending undertaken as well as innovative outputs generated. Nevertheless the CIS itself is still in its infancy and has been subject to considerable theoretical criticism. Updating the CIS to address some of these issues has led to improvements such as adding a section about wider forms of innovation and sampling the service sector as well as including details about cooperation partners and information sources used for innovation.

Nevertheless many limitations still exist and should be addressed. The CIS lacks a thorough treatment of organisational changes taking place within the firm. There are also problems associated with efforts when filling out the survey which are in parts likely related to not explicitly spelling out what "innovation activities" (CIS 4), "innovation related activity" (CIS 5) and "innovation activity" (CIS 6) or similar terms across the very same survey round are. It is thus unclear to respondents and hence researchers what is being referred to in: the questions about these sources of information used for such activities, the reason for not undertaking and constraints to such activities, whether firms had abandoned and ongoing (CIS 4) or incomplete (CIS 5 and CIS 6) activities and lastly in the CIS 6 whether they cooperated on such activities. Is it innovative inputs, outputs or both and does it include wider forms of innovation? This is aggravated by the definition of "innovation" provided at the start of the survey with a much narrower technological definition of innovation found in the CIS 5 and CIS 6 compared to the one included in the CIS 4. The issue is somewhat implicitly rectified in the CIS 6 through its design putting wider innovation under the heading of "Innovation Activity" but as just noted the definition given to the respondents about what "innovation" is actually suggests the opposite. At the same time the usefulness of the survey has been reduced by limiting the response to certain parts of the survey to firms that fall under the definition of "innovation active"[92] in the CIS 5 and the CIS 6. However this does not necessarily imply that the firms have no capacity to introduce innovations and thus their exclusion means information about the innovation potential of firms is lost. It is also not clear why respondents are no longer explained the significance of the survey as well as providing some signposting as to what the survey is about as in the CIS 3. Furthermore change of the questions about rating methods of appropriation into actual introduced appropriation methods with the CIS 6 means this data is no longer comparable to that found in previous survey rounds. Ideally both types of information should be obtained. Likewise the change in who the question about barriers of innovation is directed at means survey rounds in this area are not comparable.

[92] Firms that introduced product innovations, process innovations, wider forms of innovation or indicated to have ongoing or abandoned innovation activities during the survey period.

Cleaning and re-weighting data according to the CIS 5 population sample has been applied to improve comparability of survey rounds that where based on quite different underlying populations that are unlikely to be purely the result of natural exit and entry of firms. Nonetheless differences in response rates and statistics still persist after this correction some of which are difficult to explain while others are likely the results of changes in its design described previously resulting in differing measurement errors. It is unclear why individual survey rounds have an overlap of one year each. This means that one out of two year's innovation(s) will be recorded within two surveys and thus as twice the actual innovative output in a panel data set. Also the information about R&D spending figures is only available in the last year, thus a panel would only include information for every second year only in terms of R&D spending. The varying measurement errors across surveys will lead to spurious correlations being identified overshadowing any dynamic changes. This together with the just mentioned issues of overlap and missing info on R&D in every second year suggests that the UK CIS is simply unfit for panel data analysis, this hypothesis stands as there are no examples of time series analysis based on the UK CIS. It hence seems of paramount importance to introduce a clearer and consistent design overcoming the aforementioned issues to be able to conduct time series analysis.

An alternative approach would be to "fix" the object type nature of the survey "cutting up" the innovation process and thus causality between innovative inputs and outputs by clearly linking questions to any or the main innovation introduced during the first year of the survey period.

Lastly it is not clear why information about number of employees in R&D activities[93]have been dropped after the CIS 3 and the information on policy support considerably curtailed after the CIS 3 and dropped altogether it in the CIS 5 as well as the CIS 7.

While this may seem an extensive list of criticisms it is for one a disclaimer that has to be kept in mind when looking at differences in results across survey rounds found

[93] Though clearly specified as measure of innovative activity in the Frascati manual (OECD, 1963).

in this chapter as well as in the applications to come and the limitations imposed upon them. The CIS after all is still the most extensive and comparable firm level innovation survey that exists over time and across countries[94]. As evidenced by the list of research for the UK alone presented in the introductory chapter it has provided important insights into the innovation process as it takes place in the private sector.

This chapter has contributed to the literature by highlighting the changes in CIS survey design over time and the resulting differences in measurement errors leading to differences in observed mean values of information across surveys. It also has pointed out where the survey design is problematic and suggested improvements. At the same time these very changes that have been pointed out across the surveys provide grounds for analysis across them to see what their impact is on research that can be carried out and its results. It thus provides further motivation to do research on the Community Innovation Survey after the CIS 3, besides the large increase in its underlying population to more comprehensively cover the service sector starting with the CIS 4. Overall it seems of the uttermost importance to ensure consistency at least to a core of the survey in the future to allow for comparability of variables, be it for time series work or trend analysis.

[94] For more details on the comparability of the CIS across countries see Abramovsky, Jaumandreu, Kremp and Peters (2004).

2.7. Appendix – Missing Responses & Applied Cleaning

The UK Community Innovation Survey is voluntary. One could thus expect firms with more limited resources and a lack of interest in innovation to be less likely to fill out the survey. To check if there is a bias in not responding to the survey, the ONS carried out the questionnaire over phone for a random sample of those that the CIS 2 survey was sent to but that did not reply and apparently found there to be no significant response differences (Tether, 2001) which suggests that no bias can arise due to firms not responding to the survey. Upon request the ONS has indicated that also for the more recent survey rounds telephone follow ups are conducted to obtain answers to missing questions and to affect enterprises to respond to the survey. It is not clear why unlike in many other countries the CIS is not simply made compulsory.

The extent to which enterprises have filed out the questionnaire varies considerably. If analysis is carried out without some firms due to missing observations for specific questions in the survey, weights would need readjustment so that observations are representative again. Since not providing an answer occurs across the different questions sets this would require re-weighting at each stage, for instance when generating a tabulation for a certain question and then latter doing a regression analysis based on several questions one would have to use different weights. As this is rather time consuming and as non-response to questions seems random the analysis simply sticks to the original[95] weighting. The mean value for each variable with adjusted weights where responses were missing was visually inspected compared to the mean obtained without adjusted weight and they were very similar thus it is assumed that non-response to a certain questions is random[96] and hence does not introduce a bias. Nevertheless the issue should not be put aside that lightly and is closely related to the discussion about measurement errors.

[95] Albeit adjusted to the population underlying the CIS 5.
[96] This is an assumption and the comparability of results for different weights is in no way a proof that this is true.

As noted the extent to which firms responded to the survey and the efforts in filling out the survey have differed. Consequently statistics may be biased. Some examples of efforts by firms in filling out the survey (or potentially problems with scanning of the answers by the ONS) are now provided. Firms were asked who their main customer is and were supposed to only choose one option. In the CIS4 about 300 firms chose at least 2 options. There are also a number of firms[97] that indicated to have spent on the "acquisition of machinery, equipment and software" as well as on "marketing expenditures" in the last year of the survey which did not report to have carried out any such activities in the previous question set which asks whether firms have undertaken this sort of activities over the whole survey period. Also a few firms answering the question on which markets they sold to only indicated that they have not sold to a certain market while leaving the other two options blank. Lastly there is as noted previously considerable confusion about question q1110 in the CIS 5 which is about "whether firms did undertake any product or process innovation during the survey period". Subsequently respondents are asked if they responded negatively to the above question to skip the questions about effects of innovations. Nevertheless around 900 that responded negatively and around 100 that did not respond at all to the qualifier question ignored the instructions and responded to this question set.

Those enterprises that have not filled out the relevant information needed for a certain analysis have simply been left out for these. A hierarchical approach in deletion of observations for the analysis has been adopted. This means at each stage the most information possible from the dataset is used. However if other information allows to conclude what the relevant answer is the variables have been recoded. Let's now look at the specific cleaning procedure used for each CIS question in turn. For details of the questions discussed here please refer to the end of this section where the different survey forms are inserted.

The question regarding whether product innovations were new to the firm or the market (0710, 0720) if missing were re-coded in the affirmative if a positive innovative sales intensity (0810, 0820) had been reported. Also if respondents

[97] Exact figures can not be provided since considered disclosive by the SDS.

answered yes to any of the questions relating to who developed their product innovations (0610, 0620, 0630) or the previous questions on whether product innovations were new to the market or new to the firm but had not indicated that they carried out any product innovation (both good or service) the created variable reflecting product innovation was recoded to reflect that they had actually carried out product innovation[98]. Similarly the question on process innovation (0900) if missing but the respondent had reported where their process innovation was developed (1010,1020,1030) or that new to the industry process innovations had been introduced (1100) was recoded accordingly.

Some cleaning seems to have been done by the ONS beforehand. Questions relating to innovative outputs (that is whether firms had goods or service innovations and consequently product innovations as well process innovations) had no missing values. If answers have simply been recoded to zero if missing this is quite a stark assumption, however this seems the only plausible explanation as to the approach followed alternatively the ONS may have discarded all surveys where no response to these three crucial questions was obtained – any of these approaches were denied by the ONS upon request. Firms not indicating whether they had carried out innovative activities does not necessarily imply that they had not carried out any, they may simply not want to disclose this information.

For those firms that reported any amount spent on innovative activities in the last year of the survey period (question 14) the respective answerers relating to whether such activities were undertaken during the survey period (question 13) were recoded to reflect that they had undertaken the activity if necessary. This had to be done for the newly constructed composite measure of ‘Acquisition of machinery, equipment and software’ and ‘Market introduction of innovations’[99] for the CIS 5 and the CIS 6[100]. This suggests that firms could not really identify what exactly it was they were spending on in terms of the newly offered sub-options.

[98] Though note that from this one could not infer whether it was good or service innovation.
[99] Constructed based on at least one positive response obtained in the now extended question sets to include more sub-options, which could not be readjusted hence as their sub-options did not exist in the question about spending on innovative activities.
[100] Numbers here can not be specified since deemed disclosive by SDS.

Note though that while the information about innovative activity spending (question 14) refers to spending in the last year of the survey period only, their dummy counterpart in (question 13) refers to the whole of the survey period, thus this adjustment neglects if a firm would have reported spending figures in the two previous years but did not respond to whether they carried out innovative activities (question 13).

Beyond these adjustments for the question sets containing several questions with yes, no or other options in one group (questions 2, 12, 13, 16, 19, 21, 22 , 23)[101] all missing observations were replaced by zero if the respondents had responded to at least one question in the question set. This may have introduced a bias, however since around 95% of the respondents at one point or another had missing answers in a question set while at the same time having at least one answer to the question set not recoding them would have meant an unacceptable loss of information. For each individual question set the adjusted proportion of the population has not been larger than 5%.

[101] As question 7, about whether the firm introduced an innovation new to the market or just new to the firms, is very important this adjustment procedure has not been applied at the expense of losing observations. This was also done since for the CIS 4 the question’s wording may have lead respondents to believe that they should tick one of the 2 by 2 response matrix, starting from the CIS 5 the way to respond here was clarified.

2.8. Appendix – CIS 4 Survey Form

UK Innovation Survey

Purpose of the Questionnaire:

The purpose of this questionnaire is to collect information about innovation in the UK between 2002 and 2004. To be able to compare enterprises with and without innovation activities, we request all enterprises to respond to all questions, unless otherwise instructed.
The results of this survey will published, free, on the Department of Trade and Industry website: www.dti.gov.uk and the National Statistics website: www.statistics.gov.uk

If your enterprise is part of a larger corporate group, please answer all questions only for those units in the UK for which you are responsible.

An enterprise is defined as the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain autonomy in decision making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more location. An enterprise may be a sole legal unit.

Information Required and Definition of Innovation

This questionnaire asks for information relating to innovation activities. For the purpose of this survey,

Innovation is defined as major changes aimed at enhancing your competitive position, your performance, your know-how or your capabilities for future enhancements. These can be new or significantly improved goods, services or processes for making or providing them. It includes spending on innovation activities, for example on machinery and equipment, R&D, training, goods and service design or marketing

Where possible, answers should be provided relating to activity during the three calendar years 2002 to 2004. Where precise figures cannot be provided for the calendar years, your best estimates are acceptable.

Completing your return

This questionnaire will be scanned, therefore please:

- Complete in black ink
- Ensure letters and numbers are printed and centred within each box
- Do not use commas [,] or dashes [-]
- Do not cross sevens [7] or zeros [Ø]

for example 1,702,000 = [ ][ ][ ][1][7][0][2][0][0][0]

Please give details of the person we should contact with any queries about this return

Please use block capitals

Name of person to be contacted if necessary

Telephone no. Ext.

Fax no.

144101

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General information about your enterprise

1. Is your enterprise[1] part of an enterprise group? (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group may serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.)

Please X *one box only*

Yes X

No X 0100

If your enterprise is part of an enterprise group, please answer all further questions only for your enterprise in the UK. Do not include results for subsidiaries or parent enterprises outside of the UK.

2. In which geographic markets did your enterprise sell goods and/or services during the three year period 2002-2004?

For each option please X *one box only*

	Yes	No	
Local/regional within the UK[2]	X	X	0210
UK[3]	X	X	0220
Other Europe	X	X	0230
All other countries	X	X	0240

3. Which of the following best defines the main customers for your enterprise's goods and/or services during the three-year period 2002-2004?

Please X *one box for the most appropriate option*

Other businesses	X	0310
Public sector	X	0320
Consumers	X	0330

4. Was your enterprise established after 1 January 2000?

Yes X

No X 0400

[1] See definition of an enterprise on page 2
[2] Within approximately 100 miles of your enterprise
[3] Within the UK but more than 100 miles away from your enterprise

Product (good or service) innovation

A product innovation is the market introduction of a new good or service or a significantly improved good or service with respect to its capabilities, such as quality, user friendliness, software or subsystems. The innovation must be new to your enterprise, but it does not need to be new to your market. It does not matter if the innovation was originally developed by your enterprise or by other enterprises.

5. During the three-year period 2002-2004, did your enterprise introduce:

	Yes	No	
New or significantly improved goods. (Exclude the simple resale of new goods purchased from other enterprises and changes of a purely cosmetic nature)	X	X	0510
New or significantly improved services	X	X	0520

If no to both options above, please go to question 9, otherwise:

6. How were these products (goods or services) developed?

Please X one box only for the most appropriate option

Mainly by your enterprise or enterprise group	X	0610
Mainly by your enterprise together with other enterprises or institutions	X	0620
Mainly by other enterprises or institutions	X	0630

7. Were any of your product innovations during the three-year period 2002-2004:

		Yes	No	
New to your market?	Your enterprise introduced a new good or service onto your market before your competitors	X	X	0710
Only new to your enterprise?	Your enterprise introduced a new good or service that was essentially the same as a product already available from your competitors in your market	X	X	0720

8. Please estimate how your total turnover [4] in 2004 was distributed between the categories below. ***(Informed estimates are acceptable here)***

Products introduced during 2002-2004 that were new to your market	%	0810
Products introduced during 2002-2004 that were new to your enterprise but not new to your market	%	0820
Products introduced during 2002-2004 that were significantly improved	%	0830
Products that were unchanged or only marginally modified during 2002-2004 (include the resale of new goods or services purchased from other enterprises)	%	0840
Total turnover in 2004	1 0 0 %	

[4] For Credit institutions: Interests receivable and similar income, for insurance services: Gross premiums written

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Process innovation

Process innovation is the use of new or significantly improved methods for the production or supply of goods and services. The innovation must be new to your enterprise, but it does not need to be new to your industry. It does not matter if the innovation was originally developed by your enterprise or by other enterprises. Purely organisational or managerial changes should not be included - these are covered at question 23.

9. During the three-year period 2002-2004, did your enterprise introduce any new or significantly improved processes for producing or supplying products (goods or services) which were new to your enterprise?

Yes X

No X 0900 → Please go to question 12

10. How were these processes developed?

Please X the most appropriate option

Mainly by your enterprise or enterprise group	X	1010
Mainly by your enterprise together with other enterprises or institutions	X	1020
Mainly by other enterprises or institutions	X	1030

11. During the three-year period 2002-2004, did your enterprise introduce any new or significantly improved processes for producing or supplying products (goods or services) which were new to your industry?

Yes X

No X 1100

Effects of innovation

12. How important were each of the following effects of your product (good or service) and/or process innovations introduced during the three-year period 2002-2004?

	Degree of importance				
	Please X one box for each category				
	Not relevant	Low	Medium	High	
Increased range of goods or services	X	X	X	X	1210
Entered new markets or increased market share	X	X	X	X	1220
Improved quality of goods or services	X	X	X	X	1230
Improved flexibility of production or service provision	X	X	X	X	1240
Increased capacity for production or service provision	X	X	X	X	1250
Reduced costs per unit produced or provided	X	X	X	X	1260
Reduced environmental impacts or improved health and safety	X	X	X	X	1270
Met regulatory requirements	X	X	X	X	1280
Increased value added	X	X	X	X	1290

Innovation activities and expenditures

13. During the three-year period 2002-2004, did your enterprise engage in the following innovation activities?

Please X one box for each category

		Yes	No	
Intramural (in-house) R&D	Creative work undertaken within your enterprise on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes	X	X	1310
Acquisition of R&D (extramural R&D)	Same activities as above, but purchased by your enterprise and performed by other companies (including other enterprises within your group) or by public or private research organisations	X	X	1320
Acquisition of machinery, equipment and software	Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes, or delivery methods	X	X	1330
Acquisition of external knowledge	Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organisations	X	X	1340
Training	Internal or external training for your personnel specifically for the development and/or introduction of innovations	X	X	1350
All forms of Design	Expenditure on design functions for the development or implementation of new or improved goods, services and processes. Expenditure on design in the R&D phase of product development should be excluded.	X	X	1360
Market introduction of innovations	Activities for the market preparation and introduction of new or significantly improved goods and services, including market research and launch advertising	X	X	1370

14. Please estimate the amount of expenditure in each innovation activity in 2004, either from management accounting information or using informed estimates:

Intramural (in-house) R&D	0 0 0	1410
Acquisition of R&D (extramural R&D)	0 0 0	1420
Acquisition of machinery, equipment and software	0 0 0	1430
Acquisition of external knowledge	0 0 0	1440
Training	0 0 0	1450
All forms of Design	0 0 0	1460
Marketing expenditures	0 0 0	1470

Ongoing or abandoned innovation activities

15. During the three-year period 2002-2004, did your enterprise have any innovation activities to develop product or process innovations that you had to abandon or which were ongoing at the end of 2004?

Yes X

No X 1500

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Sources of information and co-operation for innovation

16. How important to your enterprise's innovation activities during the three-year period 2002-2004 were each of the following information sources?

Degree of importance

Please ☒ one box for each category

	Information source	Not used	Low	Medium	High	
Internal	Within your enterprise or enterprise group	☒	☒	☒	☒	1601
Market sources	Suppliers of equipment, materials, services, or software	☒	☒	☒	☒	1620
	Clients or customers	☒	☒	☒	☒	1630
	Competitors or others enterprises in your industry	☒	☒	☒	☒	1640
	Consultants, commercial labs, or private R&D institutes	☒	☒	☒	☒	1650
Institutional sources	Universities or other higher education institutions	☒	☒	☒	☒	1660
	Government or public research institutes	☒	☒	☒	☒	1670
Other sources	Conferences, trade fairs, exhibitions	☒	☒	☒	☒	1680
	Scientific journals and trade/technical publications	☒	☒	☒	☒	1690
	Professional and industry associations	☒	☒	☒	☒	1610
	Technical, industry or service standards	☒	☒	☒	☒	1611

17. Did your enterprise co-operate on any of your innovation activities with other enterprises or institutes during the three-year period 2002-2004? Innovation co-operation is active participation with other enterprises or non-commercial institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

Yes ☒

No ☒ 1700 → Please go to question 19

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18. Which types of co-operation partner did you use and where were they located?

Type of co-operation partner

Please X *all that apply*

		Local/ Regional within UK[5]	UK national[6]	Other Europe	All other countries
A.	Other enterprises within your enterprise group	X 1811	X 1812	X 1813	X 1814
B.	Suppliers of equipment, materials, services, or software	X 1821	X 1822	X 1823	X 1824
C.	Clients or customers	X 1831	X 1832	X 1833	X 1834
D.	Competitors or other enterprises in your industry	X 1841	X 1842	X 1843	X 1844
E.	Consultants, commercial labs, or private R&D institutes	X 1851	X 1852	X 1853	X 1854
F.	Universities or other higher education institutions	X 1861	X 1862	X 1863	X 1864
G.	Government or public research institutes	X 1871	X 1872	X 1873	X 1874

[5] Within approximately 100 miles of your enterprise
[6] Within the UK but more than 100 miles away from your enterprise

Continued overleaf

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Barriers to innovation

19. During the three-year period 2002-2004, how important were the following factors as constraints to your innovation activities or influencing a decision not to innovate?

Degree of importance

Please X one box for each category

		Factor not experienced	Low	Medium	High	
Cost factors	Excessive perceived economic risks	X	X	X	X	1901
	Direct innovation costs too high	X	X	X	X	1902
	Cost of finance	X	X	X	X	1903
	Availability of finance	X	X	X	X	1904
Knowledge factors	Lack of qualified personnel	X	X	X	X	1905
	Lack of information on technology	X	X	X	X	1906
	Lack of information on markets	X	X	X	X	1907
Market factors	Market dominated by established enterprises	X	X	X	X	1908
	Uncertain demand for innovative goods or services	X	X	X	X	1909
Other factors	Need to meet UK Government regulations	X	X	X	X	1910
	Need to meet EU regulations	X	X	X	X	1911

Enterprises with no innovation activity

20. If your enterprise had no innovation activity during the three-year period 2002-2004, please indicate why it has not been necessary or possible to innovate.

	Yes	No	
No need due to prior innovations	X	X	2011
No need due to market conditions	X	X	2020
Factors constraining innovation	X	X	2030

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Protection methods for innovation

21. For the three-year period 2002-2004, please indicate the importance to your enterprise of each of the following methods to protect innovations?

Degree of importance

Please X one box for each category

		Not used	Low	Medium	High	
Formal	Registration of design	X	X	X	X	2110
	Trademarks	X	X	X	X	2120
	Patents	X	X	X	X	2130
	Confidentiality agreements	X	X	X	X	2140
	Copyright	X	X	X	X	2150
Strategic	Secrecy	X	X	X	X	2160
	Complexity of design	X	X	X	X	2170
	Lead-time advantage on competitors	X	X	X	X	2180

Public support for innovation

22. During the three-year period 2002-2004, did your enterprise receive any public financial support for innovation activities from the following levels of government?

Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector under contract.

	Yes	No	
Local or regional authorities	X	X	2210
Central Government or devolved administrations (including their government agencies or ministries)	X	X	2220
If yes, did your enterprise claim a tax credit for R&D performed between 2002 and 2004	X	X	2230
The European Union (EU)	X	X	2240
If yes, did your enterprise participate in the EU's 5th (1998-2002) or 6th (2003-2006) Framework Programme for Research and Technical Development	X	X	2250

Wider innovation

This section seeks to investigate new or significantly amended forms of organisation, business structures or practices, aimed at step changes in internal efficiency of effectiveness or in approaching markets and customers.

23. Did your enterprise make major changes in the following areas of business structure and practices during the three-year period 2002-2004?

Please X one box for each category

	Yes	No	
Implementation of a new or significantly changed corporate strategy	X	X	2310
Implementation of advanced management techniques within your enterprise e.g. knowledge management systems, Investors in People	X	X	2320
Implementation of major changes to your organisational structure e.g. introduction of cross-functional teams, outsourcing of major business functions.	X	X	2330
Implementation of changes in marketing concepts or strategies, e.g. packaging or presentational changes to a product to target new markets, new support services to open up new markets.	X	X	2340

Basic economic information on your enterprise

Informed estimates are acceptable if exact figures are not available

24. What was your enterprises total turnover for 2002 and 2004? Turnover is defined as the market sales of goods and services based on the amount earned; include exports and taxes, but exclude VAT.

2002		2004	
,000	2410	,000	2420

25. What was your enterprise's total number of employees in 2002 and 2004?[7]

2002		2004	
	2510		2520

26. Approximately what proportion of your enterprise's employees in 2004 were educated to degree level or above in the following?

	2004	
Science and engineering subjects	%	2610
Other subjects	%	2620

[7] Estimated annual average - part-time staff should be converted to 'full-time equivalents'

27. **If you would like to make any comments on your approach to innovation, or if you would like to provide us with any feedback on this questionnaire, please feel free to do so in the box below:**

2700

28. **How long has it taken you to complete this questionnaire?**
Include: any time spent extracting information from your accounting systems and collating data over and above normal accounting operations

☐☐ Hrs ☐☐ Mins 2800

Thank you for your co-operation

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2.9. Appendix – CIS 5 Survey Form

UK Innovation Survey

Purpose of the Questionnaire:

The purpose of this questionnaire is to collect information about innovation in the UK between 2004 and 2006. To be able to compare businesses with and without innovation activities, we request all businesses to respond to **all** questions, unless otherwise instructed.

The results of this survey will be freely available on the Department of Trade and Industry website: www.dti.gov.uk and the National Statistics website: www.statistics.gov.uk

Information Required

Section A - General Business Information
Section B - Product (Goods or Service) Innovation
Section C - Process Innovation
Section D - Innovation Related Activity
Section E - Strategic Innovation
Section F - General Economic Information

Definition of Innovation

Innovation, for the purpose of this survey, is defined as **new** or **significantly improved products (goods or services)** and/or the **processes** used to produce or supply them, that the business has introduced, regardless of their origin. These may be just new to the business or new to the market. Investments for future innovation and changes that the business has introduced at a strategic level (in organisation and practices) are also covered.

Where precise figures cannot be provided for the three year period 1 January 2004 - 31 December 2006 **your best estimates are acceptable.**

How to complete the Questionnaire

This questionnaire will be scanned, therefore please:

- Complete in **black ink**
- Ensure letters and numbers are PRINTED and centred within each box
- **Do not** cross sevens [7] or zeros [0]

Please provide details of the person we should contact if we have any queries regarding the information returned on this questionnaire.

Contact name

Telephone number Ext.

Fax number.

Please keep a record of the time it takes to complete this questionnaire. You are asked to record this at the end of the questionnaire.

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Please complete this questionnaire for the business named on the front page.

If this business is part of an enterprise group, please answer all further questions only for this business in the UK. Do not include results for subsidiaries or parent enterprises outside of the UK.

Section A - General Business Information

During the 3 year period 1 January 2004 - 31 December 2006

1. in which geographic markets did this business sell goods and/or services?

For every category you must either ☒ *yes or no*

	Yes	No	
UK regional *Within approximately 100 miles of this business*	☐	☐	0210
UK national	☐	☐	0220
Other Europe	☐	☐	0230
All other countries	☐	☐	0240

2. which of the following best define the main customer(s) for this business's goods and/or services?

Please ☒ *all that apply*

Other businesses	☐	0310
Public Sector *For example, Government, Public Authorities*	☐	0320
Consumers *For example, Households*	☐	0330

3. did any of the following significant changes occur to this business?

Please ☒ *all that apply*

The business was established	☐	0410
Turnover increased by at least 10% due to merger with another business or part of it	☐	0420
Turnover decreased by at least 10% due to sale or closure of part of the business	☐	0430
None of the above	☐	0440

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Section B - Product (goods or service) Innovation

In this section, include all **new** goods or services or **significantly improved** goods or services e.g. in quality, user friendliness, timeliness. The innovation, although new to this business, does not need to be new to the market. Include all product innovations, regardless of their origin.

During the 3 year period 1 January 2004 - 31 December 2006

For each option please ☒ one box only

4. did this business introduce:

	Yes	No	
New or significantly improved goods? (Exclude the simple resale of goods purchased from other businesses and changes of a purely cosmetic nature)......	☒	☒	0510
New or significantly improved services?......	☒	☒	0520

STOP **If you answered no to both options above, please go to question 8**

5. were these products developed mainly by:

please ☒ one box only

This business or enterprise group	☒	0610
This business with other businesses or organisations......	☒	0620
Other businesses or organisations......	☒	0630

6. were any of your product innovations:

For each category please ☒ either yes or no

	Yes	No	
New to your market? This business introduced a new good or service onto your market before your competitors......	☒	☒	0710
Only new to this business? This business introduced a new good or service that was essentially the same as a product already available from your competitors......	☒	☒	0720

1 4 4 2 0 3

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11. **Did this business undertake any product (goods or services) or process innovations during the period 1 January 2004 - 31 December 2006?**

Yes ☐

No ☐ → Go to Q13 1110

Determining factors for innovation

12. **During the 3 year period 1 January 2004 - 31 December 2006, how important were each of the following factors in your decision to innovate (product(s) and/or process(es))?**

Please ☒ one box for each category

	High	Medium	Low	Not applicable	
Increasing range of goods or services	☐	☐	☐	☐	1210
Entering new markets or increased market share	☐	☐	☐	☐	1220
Improving quality of goods or services	☐	☐	☐	☐	1230
Improving flexibility of production or service provision	☐	☐	☐	☐	1240
Increasing capacity for production or service provision	☐	☐	☐	☐	1250
Reducing costs per unit produced or provided	☐	☐	☐	☐	1260
Reducing environmental impacts or improved health and safety	☐	☐	☐	☐	1270
Meeting regulatory requirements	☐	☐	☐	☐	1280
Increasing value added	☐	☐	☐	☐	1290

Section D - Innovation Related Activity

Innovation related activities and expenditures

13. **During the 3 year period 1 January 2004 - 31 December 2006, did this business engage in the following innovation related activities?**

For each category please X *either yes or no*

	Yes	No	
Internal R&D			
Creative work undertaken within this business on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes	☐	☐	1310
Acquisition of external R&D			
Same activities as above, but purchased by this business and performed by other companies (including other businesses within your group) or by public or private research organisations	☐	☐	1320
Acquisition of machinery, equipment and software			
Advanced machinery	☐	☐	1331
Computer hardware	☐	☐	1332
Computer software	☐	☐	1333
Acquisition of external knowledge			
Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other businesses or organisations	☐	☐	1340
Training			
Internal or external training for your personnel specifically for the development and/or introduction of innovations	☐	☐	1350
All forms of Design			
Expenditure on design functions for the development or implementation of new or improved goods, services and processes. Expenditure on design in the R&D phase of product development should be excluded	☐	☐	1360
Market introduction of innovations			
Changes to product or service design	☐	☐	1371
Market research	☐	☐	1372
Changes to marketing methods	☐	☐	1373
Launch advertising	☐	☐	1374

14. **For each of the main innovation related activities in question 13, please ESTIMATE the amount of expenditure for the year 2006**

Please round to the nearest £ thousand

Internal R&D	,000	1410
Acquisition of external R&D	,000	1420
Acquisition of machinery, equipment and software	,000	1430
Acquisition of external knowledge	,000	1440
Training	,000	1450
All forms of design	,000	1460
Marketing expenditures	,000	1470

Sources of information and co-operation for innovation

During the 3 year period 1 January 2004 - 31 December 2006

15. **how important to this business's innovation related activities were each of the following information sources?**

Please ☒ *one box for each category*

	High	Medium	Low	Not used	
Within your business or enterprise group	☒	☒	☒	☒	1601
Suppliers of equipment, materials, services, or software	☒	☒	☒	☒	1620
Clients or customers	☒	☒	☒	☒	1630
Competitors or other businesses in your industry	☒	☒	☒	☒	1640
Consultants, commercial labs, or private R&D institutes	☒	☒	☒	☒	1650
Universities or other higher education institutions	☒	☒	☒	☒	1660
Government or public research institutes	☒	☒	☒	☒	1670
Conferences, trade fairs, exhibitions	☒	☒	☒	☒	1680
Scientific journals and trade/technical publications	☒	☒	☒	☒	1690
Professional and industry associations	☒	☒	☒	☒	1610
Technical, industry or service standards	☒	☒	☒	☒	1611

Sources of information and co-operation for innovation

During the 3 year period 1 January 2004 - 31 December 2006

16. **did this business co-operate on any innovation activities with other businesses or organisation?**
Both partners do not need to commercially benefit.
Exclude routine sub-contracting out of work with no active co-operation.

Yes ☐

No ☐ → Please Go to Q 18 1700

17. **which types of co-operation partner did this business use and where were they located?**

Please ☒ *all that apply*

	UK regional	UK national	Other Europe	All other countries
Other business within your enterprise group	☐ 1811	☐ 1812	☐ 1813	☐ 1814
Suppliers of equipment, materials, services, or software	☐ 1821	☐ 1822	☐ 1823	☐ 1824
Clients or customers	☐ 1831	☐ 1832	☐ 1833	☐ 1834
Competitors or other businesses in your industry	☐ 1841	☐ 1842	☐ 1843	☐ 1844
Consultants, commercial labs, or private R&D institutes	☐ 1851	☐ 1852	☐ 1853	☐ 1854
Universities or other higher education institutions	☐ 1861	☐ 1862	☐ 1863	☐ 1864
Government or public research institutes	☐ 1871	☐ 1872	☐ 1873	☐ 1874

Protection methods for innovation

During the 3 year period 1 January 2004 - 31 December 2006

18. **please indicate the importance to this business of each of the following methods to protect innovation?**

Please ☒ one box for each category

	High	Medium	Low	Not used	
Registration of design	☒	☒	☒	☒	2110
Trademarks	☒	☒	☒	☒	2120
Patents	☒	☒	☒	☒	2130
Copyright	☒	☒	☒	☒	2150
Confidentiality agreements	☒	☒	☒	☒	2140
Secrecy	☒	☒	☒	☒	2160
Complexity of design	☒	☒	☒	☒	2170
Lead-time advantage on competitors	☒	☒	☒	☒	2180

Abandoned and Incomplete Innovation Activities

During the 3 year period 1 January 2004 - 31 December 2006

19. **did this business have any innovation activities to develop new product or process innovations that:**

For each option please ☒ either yes or no

	Yes	No	
were abandoned	☒	☒	1510
were incomplete	☒	☒	1520

Constraints on Innovation

During the 3 year period 1 January 2004 - 31 December 2006

20. **how important were the following factors as constraints on innovation activities in influencing a decision not to innovate?**

Please ☒ *one box for each category*

	High	Medium	Low	Not experienced	
Excessive perceived economic risks					1901
Direct innovation costs too high					1902
Cost of finance					1903
Availability of finance					1904
Lack of qualified personnel					1905
Lack of information on technology					1906
Lack of information on markets					1907
Market dominated by established businesses					1908
Uncertain demand for innovative goods or services					1909
Need to meet UK Government regulations					1910
Need to meet EU regulations					1911

Businesses with no innovation activity

During the 3 year period 1 January 2004 - 31 December 2006

21. **<u>if this business had no innovation activity</u>, please indicate why it has not been necessary or possible to innovate**

For each category please X either yes or no

	Yes	No	
No need due to prior innovations	☐	☐	2011
No need due to market conditions	☐	☐	2020
Factors constraining innovation	☐	☐	2030

Section E - Strategic Innovation

For the purpose of this section, include all **new** or **significantly improved** forms of organisation, business structures or practices aimed at improving internal efficiency or effectiveness or approaching markets and customers.

During the 3 year period 1 January 2004 - 31 December 2006

22. **did this business make major changes in the following areas of business structure and practices?**

For each category please X either yes or no

	Yes	No	
Implementation of a new or significantly changed **corporate strategy**	☐	☐	2310
Implementation of **new management techniques** within this business e.g. Investors in People, Just in Time, 6 Sigma	☐	☐	2320
Implementation of major changes to your **organisation structure** e.g. introduction of cross-site /teamworking	☐	☐	2330
Implementation of changes to **marketing concepts or strategies**,	☐	☐	2340

Section F - General Economic Information

23. **Please ESTIMATE this business's total turnover for the year 2006**

Please round to the nearest £ thousand.

Include: • *exports and taxes*

Exclude: • *VAT*

☐☐☐☐☐☐☐☐ ,000 2420

24. **Please ESTIMATE this business's total value of exports for the year 2006**
Please round to the nearest £ thousand.

[ ][ ][ ][ ][ ][ ][ ][ ] ,000 2440

25. **Please ESTIMATE the business's total number of employees for the year 2006**

[ ][ ][ ][ ][ ][ ][ ] 2520

26. **Of the total employees in question 25:**
Please ESTIMATE the proportion that were educated to degree level or above in

Science and engineering.......... [ ][ ][ ] % 2610

Other subjects.......... [ ][ ][ ] % 2620

27. **Would this business be willing to be approached by DTI or its appointed agents, in connection with further enquiries on innovation?**

Yes [X]

No [X] 2900

28. **In the box below, please write any additional comments that you would like to make.** 2700

[ ]

29. **How long has it taken you to complete this questionnaire?**
Include any time spent extracting information from your accounting systems and collating data over and above normal accounting operations.

[ ][ ] Hrs [ ][ ] Mins 2800

Thank you for your co-operation

1 4 4 2 1 2

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2.10. Appendix – CIS 6 Survey Form

UK Innovation Survey

Purpose of this survey:

The purpose of this survey is to collect information about innovation in the UK between 2006 and 2008. To be able to compare businesses with and without innovation activities, we request all businesses to respond to all questions, unless otherwise instructed.

Information Required

Section A - General Business Information

Section B - Innovation Activity

Section C - Goods, Services and Process Innovation

Section D - Context for Innovation

Section E - General Economic Information

Definition of Innovation

Innovation, for the purpose of this survey, is defined as new or significantly improved goods or services and/or the processes used to produce or supply all goods or services, that the business has introduced, regardless of their origin. These may be new to the business or new to the market. Investments for future innovation and changes that the business has introduced at a strategic level (in organisation and practices) are also covered.

Basis for Completion

Where precise figures cannot be provided your best estimates are acceptable.

Please complete this questionnaire for the business named on the front page.

If this business is part of an enterprise group, please answer all further questions only for this business in the UK.
Do not include results for subsidiaries or parent enterprises.

Instructions

This questionnaire will be scanned, therefore please:

- Complete in black ink
- Ensure letters and numbers are PRINTED and centred within each box
- Do not cross sevens 7 or zeros 0

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Section A - General Business Information

During the 3 year period 1 January 2006 - 31 December 2008:

1. in which geographic markets did this business sell goods and/or services?

For each category please [X] yes or no

	Yes	No		
a. UK regional within approximately 100 miles of this business	X	X	0210	MTU
b. UK national	X	X	0220	MTU
c. European countries	X	X	0230	MTU
d. All other countries	X	X	0240	MTU

2. did any of the following significant changes occur to this business?

Please [X] all that apply

a. The business was established	X	0410	MRY
b. Turnover increased by at least 10% due to merger with another business or part of it	X	0420	MRY
c. Turnover decreased by at least 10% due to sale or closure of part of the business	X	0430	MRY
d. None of the above	X	0440	MRY

3. how important were each of the following objectives to this business?

Please [X] one box for each category

	High	Medium	Low	Not applicable		
a. Profit margin on sales	X	X	X	X	0001	MRE
b. Growth in sales/turnover	X	X	X	X	0002	MRE
c. Growth in exports	X	X	X	X	0003	MRE
d. Market share in UK	X	X	X	X	0004	MRE

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Section B - Innovation Activity

4. During the 3 year period 1 January 2006 - 31 December 2008, did this business engage in the following innovation related activities?

For each category please [X] yes or no

	Yes	No		
a. Internal Research & Development Creative work undertaken within your business that increases knowledge for developing new and improved goods or services and processes	[X]	[X]	1310	MTU
b. Acquisition of external Research & Development Same activities as above, and performed by companies, including other businesses within your group, or by public or private research organisations and purchased by your business	[X]	[X]	1320	MTU
c. Acquisition of machinery, equipment and software for innovation				
Advanced machinery	[X]	[X]	1331	MTU
Computer hardware	[X]	[X]	1332	MTU
Computer software	[X]	[X]	1333	MTU
d. Acquisition of external knowledge Purchase or licensing of patents and non-patented inventions, know-how and other types of knowledge from other businesses or organisations	[X]	[X]	1340	MTU
e. Training for innovative activities Internal or external training for your personnel specifically for the development and/or introduction of innovations	[X]	[X]	1350	MTU
f. All forms of design Engagement in design activities for the development or implementation of new or improved goods, services and processes. Design activities in the R&D phase of product development should be excluded	[X]	[X]	1360	MTU
g. Market introduction of innovations				
Changes to product or service design	[X]	[X]	1371	MTU
Market research	[X]	[X]	1372	MTU
Changes to marketing methods	[X]	[X]	1373	MTU
Launch advertising	[X]	[X]	1374	MTU

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5. For each of the main innovation related activities in question 4, please ESTIMATE the amount of expenditure for the year 2008

a. Internal R&D	☐☐☐,☐☐☐,000	1410	NFR
b. Acquisition of external R&D	☐☐☐,☐☐☐,000	1420	NFR
c. Acquisition of machinery, equipment and software	☐☐☐,☐☐☐,000	1430	NFR
d. Acquisition of external knowledge	☐☐☐,☐☐☐,000	1440	NFR
e. Training for innovative activities	☐☐☐,☐☐☐,000	1450	NFR
f. All forms of design	☐☐☐,☐☐☐,000	1460	NFR
g. Market introduction of innovations	☐☐☐,☐☐☐,000	1470	NFR

Business Strategy and Practices

For the purpose of this section, include all new and significantly improved forms of organisation, business structures or practices aimed at improving internal efficiency or effectiveness of approaching markets and customers.

6. During the 3 year period 1 January 2006 - 31 December 2008, did this business make major changes in the following areas:

For each category please X yes or no

	Yes	No		
a. implementation of a new or significantly changed corporate strategy?	X	X	2310	MTU
b. implementation of new management techniques within this business? e.g. Investors in People, Just in Time, 6 Sigma	X	X	2320	MTU
c. implementation of major changes to your organisation structure? e.g introduction of cross-site /teamworking	X	X	2330	MTU
d. implementation of changes to marketing concepts or strategies?	X	X	2340	MTU

Section C - Goods, Services and Process Innovation

Goods or Services Innovation

In this section, include all new or significantly improved goods or services e.g. improvement in quality or distinct user benefits. The innovation, although new to this business, does not need to be new to the market. Include all product innovations, regardless of their origin.

During the 3 year period 1 January 2006 - 31 December 2008

7. did this business introduce:

For each category please X yes or no

	Yes	No		
a. new or significantly improved goods? Exclude the simple resale of goods purchased from other businesses and changes of a solely aesthetic nature	X	X	0510	MTU
b. new or significantly improved services?	X	X	0520	MTU

STOP If you answered no to both options above, please go to question 11

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During the 3 year period 1 January 2006 - 31 December 2008

Please X all that apply

8. were these goods or services developed mainly by:

	Goods		Services		
a. this business or enterprise group?	X	0610	X	0601	MRC
b. this business with other businesses or organisations?	X	0620	X	0602	MRC
c. other businesses or organisations?	X	0630	X	0603	MRC

9. were any of your goods and services innovations: For each category please X yes or no

	Yes	No		
a. new to your market? This business introduced a new good or service to the market before your competitors	X	X	0710	MTU
b. only new to this business? This business introduced a new good or service that was essentially the same as a good or service already available from competitors	X	X	0720	MTU

10. Of the categories below, please ESTIMATE the percentage split of this business's total turnover in 2008

a. Goods or Services introduced during 2006-2008 that were new to the market		%	0810	NCE
b. Goods or Services introduced during 2006-2008 that were new to this business but not new to the market		%	0820	NCE
c. Goods or Services introduced during 2006-2008 that were significantly improved, but not new		%	0830	NCE
d. Goods or Services that were unchanged or only marginally modified during 2006-2008 include the resale of goods or services purchased from other businesses		%	0840	NCE
Total turnover in 2008	1 0 0	%		

Process Innovation

Process Innovations are all new or significantly improved methods for the production or supply of goods or services. The innovation, although new to the business, does not need to be new to your industry. Include all process innovations, regardless of their origin.

During the 3 year period 1 January 2006 - 31 December 2008

11. did this business introduce any new or significantly improved processes for producing or supplying goods or services?

Yes X

No X → Go to Question 14 0900 MRK

12. were these processes developed mainly by: Please X one box only

a. this business or enterprise group?	X	1010	MRY
b. this business with other businesses or organisation?	X	1020	MRY
c. other businesses or organisations?	X	1030	MRY

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During the 3 year period 1 January 2006 - 31 December 2008

13. did this business introduce any new or significantly improved processes for producing or supplying goods or services which were new to your industry?

Yes ☐

No ☐ 1100 MRK

14. did this business have any innovation activities that were: For each category please X yes or no

	Yes	No		
abandoned?	☐	☐	1510	MTU
incomplete?	☐	☐	1520	MTU

15. Did you answer yes to any of questions 6, 7, 11 or 14?

Yes ☐

No ☐ → Go to Question 20 1501 MRK

Section D - Context for Innovation

16. During the 3 year period 1 January 2006 - 31 December 2008, how important were each of the following factors in your decision to innovate goods or services and/or process(es)? Please X one box for each category

	High	Medium	Low	Not applicable		
a. Increasing range of goods or services	☐	☐	☐	☐	1210	MRE
b. Entering new markets	☐	☐	☐	☐	1211	MRE
c. Increasing market share	☐	☐	☐	☐	1220	MRE
d. Improving quality of goods or services	☐	☐	☐	☐	1230	MRE
e. Improving flexibility for producing goods or services	☐	☐	☐	☐	1240	MRE
f. Increasing capacity for producing goods or services	☐	☐	☐	☐	1250	MRE
g. Increasing value added	☐	☐	☐	☐	1290	MRE
h. Reducing costs per unit produced or provided	☐	☐	☐	☐	1260	MRE
i. Improving health and safety	☐	☐	☐	☐	1270	MRE
j. Reducing environmental impacts	☐	☐	☐	☐	1212	MRE
k. Replacing outdated products or processes	☐	☐	☐	☐	1213	MRE
l. Meeting regulatory requirements	☐	☐	☐	☐	1280	MRE

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During the 3 year period 1 January 2006 - 31 December 2008:

17. how important to this business's innovation related activities was information from:

Please [X] one box for each category

	High	Medium	Low	Not applicable		
a. within your business or enterprise group?	X	X	X	X	1601	MRE
b. suppliers of equipment, materials, services, or software?	X	X	X	X	1620	MRE
c. clients or customers?	X	X	X	X	1630	MRE
d. competitors or other businesses in your industry?	X	X	X	X	1640	MRE
e. consultants, commercial labs, or private R&D institutes?	X	X	X	X	1650	MRE
f. universities or other higher education institutions?	X	X	X	X	1660	MRE
g. government or public research institutes	X	X	X	X	1670	MRE
h. conferences, trade fairs, exhibitions	X	X	X	X	1680	MRE
i. professional and industry associations?	X	X	X	X	1610	MRE
j. technical, industry or service standards?	X	X	X	X	1611	MRE
k. scientific journals and trade/technical publications?	X	X	X	X	1690	MRE

18. Did your business co-operate on any innovation activities with any of the following?

Please [X] all that apply

	UK regional	UK national	Other Europe	All other countries	
a. Other businesses within your enterprise group	X 1811	X 1812	X 1813	X 1814	MRF
b. Suppliers of equipment, materials, services, or software	X 1821	X 1822	X 1823	X 1824	MRF
c. Clients or customers	X 1831	X 1832	X 1833	X 1834	MRF
d. Competitors or other businesses in your industry	X 1841	X 1842	X 1843	X 1844	MRF
e. Consultants, commercial labs, or private R&D institutes	X 1851	X 1852	X 1853	X 1854	MRF
f. Universities or other higher education institutions	X 1861	X 1862	X 1863	X 1864	MRF
g. Government or public research institutes	X 1871	X 1872	X 1873	X 1874	MRF

19. Please go to Question 21.

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During the 3 year period 1 January 2006 - 31 December 2008:

20. please indicate why it has not been necessary or possible to innovate:

For each category please [X] yes or no

	Yes	No		
a. no need due to previous innovations	X	X	2011	MTU
b. no need due to market conditions	X	X	2020	MTU
c. other factors constraining innovation	X	X	2030	MTU

21. how important were the following factors in constraining innovation activities?

Please [X] one box for each category

	High	Medium	Low	Not applicable		
a. Excessive perceived economic risks	X	X	X	X	1901	MRE
b. Direct innovation costs too high	X	X	X	X	1902	MRE
c. Cost of finance	X	X	X	X	1903	MRE
d. Availability of finance	X	X	X	X	1904	MRE
e. Lack of qualified personnel	X	X	X	X	1905	MRE
f. Lack of information on technology	X	X	X	X	1906	MRE
g. Lack of information on markets	X	X	X	X	1907	MRE
h. Market dominated by established businesses	X	X	X	X	1908	MRE
i. Uncertain demand for innovative goods or services	X	X	X	X	1909	MRE
j. UK Government regulations	X	X	X	X	1910	MRE
k. EU regulations	X	X	X	X	1911	MRE

Protection of Innovation

22. did your enterprise:

For each category please [X] yes or no

	Yes	No		
a. apply for a patent?	X	X	2130	MTU
b. register an industrial design?	X	X	2110	MTU
c. register a trademark?	X	X	2120	MTU
d. produce materials eligible for copyright?	X	X	2150	MTU

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23. During the 3 year period 1 January 2006 - 31 December 2008, did your business receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans and equity investments. Exclude research and other innovation activities conducted entirely for the public sector under contract.

For each category please [X] yes or no

	Yes	No		
a. UK Local or regional authorities	X	X	2210	MTU
b. UK Central government	X	X	2220	MTU
c. European Union institutions or programmes	X	X	2240	MTU

Section E - General Economic Information

24. Please ESTIMATE this business's total turnover for the year:
Exclude: VAT

a. 2006	___,___,000	2410	NFR
b. 2008	___,___,000	2420	NFR

25. Please ESTIMATE the business's average number of employees for the year:

a. 2006		2510	NGT
b. 2008		2520	NGT

26. Of the employees in question 25:
Please ESTIMATE the proportion that hold a degree, e.g. BA/BSc, or higher degree, e.g. MA/Phd, PGCE, in:

a. Science or Engineering subjects	%	2610	NCE
b. Other subjects	%	2620	NCE

27. Would this business be willing to be approached by the Department of Innovation, Universities and Skills or its appointed agents, in connection with further enquiries on innovation?

Yes X

No X 2900 MRK

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28. In the box below, please write any additional comments that you would like to make.

2700

FHI

29. How long has it taken you to complete this questionnaire?
Include any time spent extracting information from your accounting systems and collating data over and above normal accounting operations.

Hrs NCB

Mins 2800 NCB

Please provide details of the person we should contact if we have any queries regarding the information returned on this questionnaire

Contact name QVA

Position in business QVA

Telephone number Ext. QVE

Thank you for completing this questionnaire

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3. Modes of Innovation, Absorptive Capacity and Appropriation

3.1. Introduction

A recent approach that helps interpretation of the extensive data contained in the CIS and other related innovation surveys is to identify “innovation modes”. These are derived by conducting factor analysis on the responses obtained from the surveys. The intention behind this is to characterize features of the innovation process. Innovation modes for this chapter are thus defined as “a set of bundles of activities which are done together (by enterprises) that can bring about a new good or service or a change in production, delivery and business processes”[102] and the cognitive landscape related to these activities. Beyond using factor analysis for deriving modes of innovation it is also by itself a useful data reduction method as it allows condensing the large question sets within the survey to smaller sets of underlying latent variables, which is the purpose it is used for in Psychometrics where it stems from. The latent variables identification means that factor analysis can be used to see if previous conceptions of innovation theory can be validated based on these firm level surveys which hence allows to check whether the surveys do capture them sufficiently or whether they themselves were misconceived[103]. Factor analysis is also applied to obtain a measure of absorptive capacity and appropriation which are used as explanatory variables in subsequent chapters’ regression models.

According to the RBV firms’ capabilities are derived from how the knowledge embedded in their employees is managed and organised, which is believed to be strongly influenced by the cognitive functioning of their managers. By similar argument absorptive capacity of individuals translates to the firm’s absorptive capacity depending on the firm’s organizational procedures (Cohen and Levinthal, 1990). The firm’s capabilities depending on their alignment within the innovation

[102] This definition is an adaptation of the one found in Lambert and Frenz (2010), the reason for the slight change in wording is explained in the literature review section.

[103] Given the infancy of the CIS this could also help redesigning questionnaires by dropping questions that do not add much in terms of capturing the fundamental firm properties relevant for innovation and including extra questions that in a similar fashion can be checked for their information content. This sort of approach is used in Psychometrics (Kline, 1994).

system translate into the nation's capabilities. As described in the literature review section of the introduction chapter, this is because firms through their interaction with the systemic environment determine the nation's economic performance. Cross country comparisons using factor analysis to identify "capabilities" that are vital for development and thus growth have a tradition of being carried out in the empirical macro literature (Adelman and Morris, 1965; Temple and Johnson, 1998; Fagerberg and Srholec, 2008). Initially though factor analysis was formalized by Pearson (1901) and its use pioneered by Spearman (1904) in psychometrics with the aim of identifying underlying cognitive traits from wide arrays of subject scores obtained from individuals. Thus it is a natural extension to investigate capabilities not just at the individual and national level by use of factor analysis but also to do so at the firm level. Given the close link between a firm's organization and its management's cognition, pointed to by the RBV, the identified factors can also be interpreted as the cognitive landscape of the firm's management, in other words its strategy.

Classifying firms or specifically the industry sector they belong to according to their innovative activities and their "sources of technology, requirements of users, and possibilities of appropriation" was first undertaken in a widely cited article by Pavitt (1984)[104]. Recent literature relying on factor analysis to do so include Hollenstein (2001, 2003), Jensen, Johnson, Lorenz and Lundvall (2007), Leiponen and Drejer (2007), Srholec and Verspagen (2008) and Lambert and Frenz (2008, 2010). While the use of factor analysis to derived latent variables for appropriability and absorptive capacity is found for the later in Jansen et al. (2005), Arbussa and Coenders (2007) and Harris and Li (2009, 2011) and for the former in Cohen et al. (2000) and Becker and Peters (2000).

This chapter's aim consists of both of these aspects. One is to generate a measure of appropriation and absorptive capacity using factor analysis that serve as explanatory variables for the regression models in the two subsequent chapters which explain innovative activity and the latter also for explaining the likehood of

[104] Paradoxly this grouping of firms is done using a subject type data set (SPRU) rather than an object type data set which is concerned with firms itself rather than the innovation.

the receipt of public support for innovation. The first of these measures provides an alternative to using past R&D activities (Cohen & Levinthal, 1989) as a proxy for absorptive capacity, and thus by construction is less biased towards the manufacturing sectors and large firms where R&D is more prevalent. Besides since information on the existence of past R&D activities can only be obtained by linking the survey across time and thus losing the largest part of the datasets it provides next to the information about the educational level of employees the only way to measure absorptive capacity[105]. While published works that use this sort of measure of absorptive capacity for the CIS data exists (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011; Schmidt, 2010) none of these are applied in the sort of analysis conducted in the next two chapter, the same is true for the appropriation measure used by Becker and Peters (2000) which while used to explain innovative activities and outputs though not following the CDM methodology was based on the 1993 Mannheim Innovation Panel for manufacturing firms only. The derivation of these measures is based on the same statistical procedure as the one to generate the modes of innovation namely factor analysis and thus is included in this chapter. However as their generation and the discussion of their theoretical underpinnings would disrupt the flow of this chapter and overextend it, they have been deferred to the appendix (section 3.8 and 3.9).

The other purpose of this chapter is to deepen the analysis of the previous one by using factor analysis to detect underlying linkages among the extensive information contained in the CIS and thereby to identify aforementioned modes of innovation[106]. This should provide a clearer understanding of the notion of "bundles of assets" that the RBV uses to explain the success of innovative firms but also be able to see if pre-existing ideas about the innovation process can be confirmed and are sufficiently captured by the survey. As Lam (2005) for instance notes there is little

[105] Educational characteristics of firm's employees are though more likely to be related to the job requirements and thus only indirectly impact absorptive capacity. The organizational procedures used for human resource management are much more vital in translating employee's absorptive capacity to that of the firm rather than their degree, see the literature review in section 3.8 for details. On the other hand the assessment of the importance of sources of information for innovative activities used for generating the absorptive capacity measure are a clear sign that the firm has the ability to gather external information and to exploit this knowledge. The limitations of this sort of measure are considered in the conclusion of this chapter.

[106] These steps are undertaken separately; a measure of absorptive capacity and appropriation is to be created for the whole sample while innovation modes are to be identified for innovation active firms only. As the approach and the idea of identifying capabilities are common to both steps they are undertaken in the same chapter.

empirical evidence on the role of organisational innovation and few attempts have yet been made to investigate the CIS, particularly in the UK, to this end. Furthermore previous work does not attempt to confirm the results across different survey sets. Solutions to factor analysis through rotational techniques can be arbitrary and thus a comparison across various surveys provides a robustness check to the results. Two similar works for the UK exists carried out by Lambert and Frenz (2008, 2010)[107] based on the CIS 4. This chapter however follows the distinct methodology of Srholec and Verspagen (2008). Their work based on the CIS 3 for 13 European countries does not use data from the UK. Thus herein lies the main contribution of this chapter, by providing evidence based on their as will be argued superior methodology for the UK. Furthermore as noted compared to both aforementioned studies and all other similar studies that have been found, this work distinguishes itself by making use of several survey rounds. This allows the often difficult judgement of the number of factors to retain to be supported by investigating consistency of these across surveys.

Srholec and Verspagen's (2008) use a hierarchical approach to factor analysis where in a first stage lower order factors are identified based on individual question sets found in the CIS. In a second stage factor analysis of these lower order factors generates higher order factors which are interpreted as innovation strategies or modes[108]. The main advantage of Srholec and Verspagen's (2008) method is that it avoids the need for arbitrary selection of variables to include in the factor analysis undertaken by most similar studies yet justified by few simply because there are no a priory reason to exclude variables. Also none of the literature on modes of innovation explains their selection in any way. Use of all the information at once however is likely to result in identification of modes that simply represent individual question sets rather than sensible innovation strategies[109]. For instance a mode of innovation could be identified that consists of wider forms of innovation only or worker skills only[110]. This sort of problem should be overcome with the

[107] These are the only two available for the UK according to the author's best knowledge.
[108] While Leiponen and Dreijer (2007) interpret their obtained factors as technology regimes.
[109] This is a major challenge the researcher faces in using factor analysis as alternative factor solutions are likely to emerge and he then has to choose the one that makes sense in terms of theoretical interpretation.
[110] As for instance seen in Lambert and Frenz (2008), a theoretical interpretation of such modes, also because they were obtained using orthogonal techniques, does not seem useful.

described two step approach. The other major advantage of this hierarchical procedure is that it enables the researcher to look closely at individual theoretical aspects covered in the survey relevant for innovation and to see whether past thinking and findings can be confirmed on the basis of the results. One can then see whether for instance the dichotomies between tacit and codified knowledge or between formal and informal appropriation methods re-emerge from the data when factor analysing the question set relating to the importance of sources of information and the one about the rating of appropriation methods. This could also help to point to gaps in the survey in that certain aspects that previous literature has clearly established simply do not emerge as latent variables and thus provide for grounds to adjust the survey or even the theory after obtaining further evidence that confirms the findings. Lastly unlike similar literature Srholec and Verspagen (2008) use oblique rotational techniques rather than orthogonal ones which allow for overlaps among the individual factors identified. Since innovative activities can be expected to be complementary this procedure allows for a more realistic representation of innovation strategies.[111]

The loose and diverse theoretical foundations as well as their methodologies used for identifying modes of innovation are discussed in the next section also providing an overview of this literature's findings. The third section then gives some background to how factor analysis works. The fourth section contains details of the data and the results of the higher order factor analysis with the final section summarizing and reflecting on the chapter. The results of the lower order factor analysis are found in the appendix, section 3.6. Likewise the literature review about absorptive capacity and appropriation and their empirical measurement are contained in the appendix, section 3.8. The results of the factor analysis to generate indices for these are contained in the subsequent section (3.9).

[111] A major reason why orthogonal rotational techniques are still so commonplace is that oblique rotational techniques are computationally less burdensome, despite this no longer being a constraint nowadays they have simply persisted as a matter of habit.

3.2. The Literature on Modes of Innovation

Evolutionary theory and the RBV posit that innovative activities even across an industry are heterogeneous rather than converging towards and ideal form as suggested by neoclassical economic theory (Nelson, 1991). Studying modes of innovation is argued to provide evidence for this perspective by identifying innovation strategies that are independent of sectoral classifications (Leiponen and Drejer, 2007; Hollenstein, 2003; Palmberg, 2004)[112]. In line with this thinking Malerba (1992) distinguishes firms "by different direction of incremental technical change, depending on their learning processes, and on their stock of knowledge and capabilities accumulated over time." Innovation modes can also be defined as "a set of bundles of activities which are done together by firms that can bring about a new good or service or a change in production, delivery and business processes"[113]. This definition is closely related to the concept of unique capabilities as defined in the RBV, in which firms are perceived as bundles of tangible and intangible resources used to generate superior performance (Penrose, 1959; Wernerfelt, 1984). The RBV stresses the strategic deployment of resources (Wernerfelt, 1984; Teece, Shuen and Pisano, 1997; Makadok, 2001) and that this is based on cognition of opportunities rather than just being the result of reducing transaction costs by streamlining activities.

Categorizing firms according to their innovation strategy is a very recent development of which not many applications can be found. The emergence of this literature is a result of the recent availability of firm level information about innovation as available from the CIS. Many of these studies refer back to Pavitt's

[112] While at first sight this may seem a paradoxical approach, it leaves a lot of room for heterogeneity and indeed confirms that there is a very large variability in innovative behaviour that cannot be traced to homogenous innovation modes. Also though innovation modes may be homogenous the way they are actually implemented by the firms may still be heterogeneous, for instance how exactly and the extent of R&D that is is still likely to vary largely across firms.

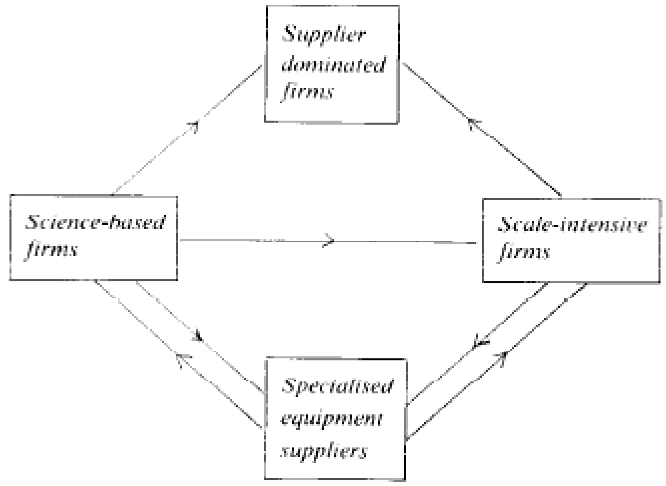
[113] This adaptation of Lambert and Frenz's (2010) definition of innovation modes as "a set or bundles of activities which are done together by firms to bring about and market a new good or service, or improve on production, delivery and business processes" is more in line with the evolutionary perspective. Notably in that it posits that variety of routines allows for selection of neither necessarily optimal nor intentional configurations. Hence the intentionality and optimality implied in Lambert and Frenz's (2010) definition has been done away with.

(1984) contribution which relates sectors innovative activities to their knowledge sources nevertheless these works as will be explained are quite distinct in spirit.

Pavitt (1984) provides the first characterisation of “intangible resources” that facilitate innovation and are firm specific and cumulative. Using the SPRU dataset about around 2000 significant innovations in the UK between 1945 and 1979, he investigates the sources of their knowledge inputs. Thereby he highlights the influence of users of firm outputs on innovation and the extent of appropriation of innovations feasible in various industry sectors. His approach is related to the knowledge generating view of the firm: the firm is only able to innovate if it has the necessary resources to access previously accumulated knowledge as well as related new information. He identifies several firm categories (see figure 3.1). The first archetype are ‘supplier dominated firms’, found in “agriculture, house building, informal household production and many professional, financial and commercial services”. According to him these are mostly engaged in “professional skills, aesthetic design, trademarks and advertising”. Another set are ‘scale intensive firms’, their scope for innovation lies in the “division of labour and other economies of scale” giving them cost advantages over competitors. A further firm archetype he makes out are ‘science based firms’ which rely on formalized R&D and are found mostly in “electronics and electrical sectors” that rely on science development in public research institutions. The fourth type of firms supplies the scale intensive and science intensive firms. They are the ‘specialised equipment suppliers’. In a later paper (Pavitt et al., 1989) this taxonomy has been extended to include ‘information intensive-firms’ and ‘specialized producers’[114]. Thus sources of knowledge have been shown to be an important and identifiable “intangible asset” of firms shaping its innovation strategy.

[114] While it may seem that technological developments may have prompted the emergence of other types of firms one of the more recent evolutions, the “new economy” can be characterised as “science-based firms” where a lot of the workforce has previously been working in universities and as production becomes more streamlined the other firm types emerge (Archibugi, 2001).

Figure 3.1, Firm Classification; Pavitt (1984)



While most of the literature on modes of innovation cites Pavitt's (1984) classification of industry sectors by their use of knowledge sources there are some notable differences in the approach they follow. First of all Pavitt's work is based on the SPRU database where innovations have been assessed by industrial experts whereas the works on modes of innovation are based on firm level questionnaires, mostly the CIS. This is self-assessed information which is of subject rather than object type nature. Self-assessment of innovations often leads to a different judgement about what innovation is compared to the perception of other stake holders, Garcia and Calantone (2002) and Massa and Testa (2008) provide empirical evidence in support. The ensuing literature has indeed identified new and different innovation strategies. This may be a result of the SPRU's neglect of incremental innovations that are likely to have been picked up by firms' self-reporting, which are less likely to be reliant on external sources of information. Duguet (2006) for instance relates incremental innovation to adoption of equipment goods and informal research, radical innovations on the other hand to firm level spillovers, intellectual property and formal internal research. Another marked difference among Pavitt's work and the literature on modes of innovation is that while Pavitt aims to classify industry sectors the modes literature tries to provide evidence on intra-sector heterogeneity and potentially show that sectoral classifications[115] are

[115] For instance the literature has previously often proxied technological opportunities, spillovers and industry concentration which are likely to impact innovation strategies by industry classification (see Cohen (1995) as well as the next chapters literature review for more details).

not very helpful when it comes to explaining sources of innovation (Palmberg, 2004), organization of innovative activities (Leiponen and Drejer, 2007), innovative activities themselves (Hollenstein, 2003, Srholec and Verspagen, 2008) or innovative strategies (Hollenstein and Arvanitis, 2001). This is related to the difficulty of assigning exact industrial classifications to firms in the first place as these are based on the sector in which the firm generated the most value added thereby ignoring all secondary fields of activity[116]. As Hollenstein (2003) and Srholec and Verspagen (2008) argue based on their results industry classifications are still useful. However they find that modes of innovation help to explain to a larger extent the observed heterogeneity in innovative activities then industry type information. Thus the modes of innovation literature rather than as Pavitt's work classifying industry sectors according to their use of knowledge sources, aims to understand the heterogeneous and unique nature of innovation. So it looks at what bundles of assets different firms are deploying irrespective of their industrial classification.

So let's now shortly turn to what the RBV and evolutionary perspective purport with respect to firm classification. The evolutionary literature has stressed the systemic context and the technological regimes of which firms are part of and how they influence the firm's innovative activities[117] (Winter, 1984; Malerba and Orsenigo, 1993, 1996). Peneder (2010) in this respect specifies that "opportunity conditions, appropriability conditions, and the cumulativeness of knowledge, together define the so-called technological regime under which a firm operates". While the evolutionary literature has highlighted the role of routines their nature does not per se lie at its focus, it is the resource based perspective that deals with them more thoroughly. The competitiveness of a firm is after all of central interest to the business literature and according to the RBV stems from the ability to build and develop firm specific capabilities and simultaneously adapt competences to the environment. These have as a result also been termed "dynamic capabilities" (Teece and Pisano, 1994). In this literature Teece (1998) classifies firm types by

[116] According to "UK Standard Industrial Classification of Economic Activities 2007" (ONS, 2007), which follows international guidelines for comparability.

[117] Though these aspects have previously mostly been related to industry sector (Malerba and Orsenigo, 1996; Breschi and Malerba, 1997; Breschi, Malerba and Orsenigo, 2000).

governance, culture and values and their external network, relating these to different types of innovation. He identifies ‘multi-product integrated hierarchy’, ‘highflex silicon valley type’, ‘virtual corporation’ and ‘conglomerate’. Diversity of firm types (also within industries), as for example McGahan and Porter (1997) argue, is seen as evidence in support of the RBV.

Beyond the systemic and resource based perspective the modes of innovation literature is also viewed as rooted in other, potentially dichotomous, but nonetheless closely related perspectives. For instance Lambert and Frenz (2010) point to the difference between “open innovation”[118] (Chesbrough, 2003) and “user innovation”[119] (von Hippel, 1988). The first approach relies on external linkages and resource inputs whereas the latter on internal developments, often by adapting bought in equipment towards firm specific needs. Lambert and Frenz (2010) believe that firms combining use of both of these approaches are more competitive and based on the modes of innovation they identify conclude to have found evidence for use of both open and user innovation. Another classification in this literature is the one used by Jensen et al. (2007) relating to the type of knowledge used for innovation. According to them the ‘science, technology and innovation mode’ (STI) involves the production and use of codified scientific and technological knowledge whereas the ‘doing, using and interaction’ (DUI) mode of innovation is based on experiences firms gain over time. They relate these conceptions to the characteristics of knowledge, its tacitness and codification (Cowan, David and Foray, 2000; Johnson, Lorenz and Lundvall, 2002). Palmberg (2004) motivates his work by pointing to the debate among whether demand pull and technology push factors drive innovation. In the spirit of Schumpeter’s Mark 1 and 2 theory Castellacci (2008) characterizes regimes as “entrepreneurial” or “widening” and “routinized” or “deepening” while Zi-Lin and Poh-Kam (2004) identify exploration type of organization that contrast with exploitation type of organization. Eventually these conceptions can be interpreted as means to clarify what the specific bundles are that the RBV has suggested makes firms competitive.

[118] Here innovation relies on external linkages with other firms and the communal exploitation of each others resources.
[119] In contrast to open innovation here firms concentrate on internal activities relying on equipment bought form the outside and adopted for firm-specific use.

More or less the empirical literature on strategies/modes/regimes of innovation is based around the aforementioned theoretical perspectives. The various linkages and knowledge sources that a firm has access to and it uses together with its internal resources including innovative inputs such as R&D spending are seen as part of strategic decisions. The aim of this literature is hence to identify strategies pursued by firms sometimes relating these to the firm's objectives which are likely to be affected by the firm's position within the market as well as the perceived extent of its market. Some of its authors (Cesaratto and Mangano, 1993; Hollenstein, 2001; 2003; Arundel and Hollanders, 2005; Leiponen and Drejer, 2007; Jensen et al., 2007) further then just identifying certain firm strategies try to classify firms by the intensity with which they use various strategies and thus acknowledge their potentially complementary nature using cluster analysis. Similarly Srholec and Verspagen (2008) point out that their identified strategies are not exclusive, that is no firm makes use of them uniquely. These strategies and or clusters are then sometimes related to performance as in Cesaratto and Mangano (1993), Hollenstein (2001,2003) and Frenz and Lambert (2008). On the other hand Arundel and Hollanders (2005) aim to generate an index of innovative performance to complement the European Innovation Scoreboard while Jensen et al. (2007) try to find evidence for how learning takes place at the firm level. Cesaratto and Mangano (1993) and Palmberg (2004) want to confirm that similar classes of firms to those identified by Pavitt (1984) exist in their countries at the time while Lambert and Frenz's (2008, 2010) work looks at whether similar innovation modes exist across European countries. Leiponen and Drejer (2007), Hollenstein (2001, 2003) as well as Srholec and Verspagen (2010) on the other hand seek to provide evidence on firm level heterogeneity and thus in support of the evolutionary perspective. While the aims of this literature are diversified the analytical procedure followed and discussed next, is very similar.

The earliest taxonomy of firms in the evolutionary literature by Pavitt (1984), as noted is actually a sectoral classification according to the use of "sources of knowledge"[120] based on the interpretation of simple statistics combined with knowledge of past sectoral and firm level studies on innovation. In a similar spirit Cesaratto and Mangano (1993), Hollenstein (2001, 2003), Palmberg (2004), Arundel and Hollanders (2005) Leiponen and Drejer (2007), Jensen et al. (2007), Srholec Verspagen (2010) and Lambert and Frenz (2008, 2010) using firm level data perform factor analysis to identify use of innovative inputs including information sources and sometimes innovative outputs to identify core strategies of innovation used by firms. All except Palmberg (2004), Srholec and Verspagen (2008) and Lambert and Frenz (2008, 2010) then go on to use cluster analysis to group firms into sets using a similar innovation strategy or a combination of innovation strategies, often identifying groups of firms that make very little use of innovation strategies. While their methodological approach is similar their inclusion of variables for the analysis varies largely, for instance Battisti and Stoneman (2010) only use 5 innovation output indicators on the other hand Srholec and Verspagen (2008) make use of almost the full set of information contained in the CIS, excluding innovative outputs though. Partly the choice of variables is limited to maintain comparability of results among countries such as in Lambert and Frenz (2010) and Arundel and Hollanders (2005) and partly due to direct objectives of the study, that is being confirmatory rather than exploratory factor analysis such as in Arundel and Hollanders (2005) as well as in Jensen et al.(2007). A shortcoming that all of this literature has in common is its reliance on cross-sectional data and thus neglect of the dynamic nature of organizational strategy. Potentially the identified strategies thus just represent different stages or parts of the innovation process.

In terms of the results of this literature Jensen et al. (2007) find evidence for their postulated knowledge management strategies and show that those firms using both Science Technology and Innovation (STI) and Doing, Using and Interacting (DUI) learning modes are the most successful innovatively. Lambert and Frenz (2008) show that their identified innovation modes are associated with superior productive performance, in their later paper (2010) they show cross country differences in the intensity of modes used. Leiponen and Drejer (2007) and Hollenstein (2003) while finding evidence for heterogeneity within industries, conclude that industrial

[120] More specifically "sources of technology, requirement of users, and possibilities for appropriation"

classifications retain their use since in terms of their identified innovation modes industries are still distinct to some extent. Furthermore Leiponen and Drejer (2007) conclude that since the heterogeneity is as present in low-tech as in high-tech sectors it is a result of strategic differentiation rather than adapting to complex environments. Cesaratto and Mangano (1993) and Leiponen and Drejer (2007) feel their results are in line with Pavitt's taxonomy of innovation behaviour though these relate to firm rather than sectoral strategies. Palmberg (2004) agrees with the last point and furthermore finds evidence for the combination of technology push and demand pull factors and argues that this finding is in line with the chain linked innovation model by Kline and Rosenberg (1986).

3.3. Methodology

Pearson (1901) explicated the mathematical foundations of factor analysis and its first well known application conducted by Spearman (1904) identified underlying latent variables that measure "general intelligence". Recently it has also seen applications in the research on innovation. Mathematically, factor analysis is a method to obtain fewer random variables than one has previously had without loss of too much information content[121]. In other words one builds an index or several based on a larger set of variables believed to represent manifestations of the measure under consideration. Opposed to principal component analysis the researcher is not focused on generating a composite measure for a set of variables but rather to identify the fundamental underlying properties that drive the observed variables. So for factor analysis one is interested in identifying theoretical concepts that generate the data that is observed, instead of as in principal component analysis trying to simplify larger amounts of information that have been collected into composite indexes. Thus the latter is not applicable in this context as the innovation modes are believed to be related to theory rather than being abstractions, similarly appropriability and absorptive capacity are theory based

[121] A more thorough treatment of factor analysis can be found for instance in Kline (1994) or Tabachnick and Fidell (2007).

conceptions[122]. Whereas a principal component analysis does not allow for an interpretation of the obtained principal components, likewise it does not allow to derive measures of absorptive capacity and appropriation. Factor analysis is termed exploratory if the researcher tries to identify an underlying structure. If one however would like to confirm pre-existing theoretical conceptions this would constitute a confirmatory factor analysis. In reality none of these abstractions exist in their pure form. After all even when one sets up a survey or data measurement one must have some kind of pre-existing conceptions of what one is after and the other way round if one wants to confirm some theoretical conception these are likely to have arisen due to some previous observations.

Mathematically factor analysis is explicated as follows. Given a set of random variables $X_1, X_2,..., X_k$ these can be represented using latent variables $Y_1, Y_2,..., Y_l$. where μ_j is the mean of X_j and e_j ($j = 1,2,..., k$) is a random error term with mean zero and finite variance and $l < k$, such that:

$$\begin{aligned} X_1 &= \mu_1 + b_{11}Y_1 + b_{12}Y_2 + ... + b_{1l}Y_l + e_1 \\ X_2 &= \mu_2 + b_{21}Y_1 + b_{22}Y_2 + ... + b_{2l}Y_l + e_2 \\ &... \\ X_k &= \mu_k + b_{k1}Y_1 + b_{k2}Y_2 + ... + b_{kl}Y_l + e_k \end{aligned} \tag{3.1}$$

Or in vector notation

$$X = \mu + BY + \varepsilon \tag{3.2}$$

The following constraints are then imposed:

1. Y and e are independent (no further variability in X can be explained by Y)
2. the mean of Y is 0, $E(Y) = 0$
3. the Ys are uncorrelated with variance 1, $\text{cov}(Y_i Y_j) = 0$ where $i \neq j$, $\text{var}(Y_i) = 1$

Now using the above it follows that:

$$\begin{aligned} &\text{cov}(X - \mu) = \text{cov}(BY + \varepsilon) \\ &= \text{cov}(BY) + \text{cov}(\varepsilon) \\ &= B\,\text{cov}(Y)B^T + \Psi \\ &\Sigma = BB^T + \Psi \end{aligned} \tag{3.3}$$

[122] PCA also analyses the whole of the variance in the variables rather then just their shared variance, as discussed in the previous chapter there is likely to be measurement errors for the variables, such introduced variability would certainly not be ignored in a PCA.

B is the "factor loading matrix" and Ψ is the covariance matrix of the error terms, which is a diagonal matrix of the variance of e, since the errors are uncorrelated. As there are an infinite number of solutions to this problem one needs to apply some other constraint to obtain a unique solution. To find a factor loading matrix B that solves this simultaneous equation system one uses the following approximation obtained from the eigenvalue-eigenvector decomposition of the variance covariance matrix Σ (assumes diagonalizability[123]), where λ are the eigenvalues and e the corresponding eigenvectors:

$$\Sigma = \sum_{i=1}^{k} \lambda_i e_i e_i^T \cong \sum_{i=1}^{l} \lambda_i e_i e_i^T = (\sqrt{\lambda_1} e_1 \cdot \sqrt{\lambda_2} e_2 \cdot \ldots \cdot \sqrt{\lambda_l} \cdot e_l) \cdot \begin{pmatrix} \sqrt{\lambda_1} e_1^T \\ \sqrt{\lambda_2} e_2^T \\ \ldots \\ \sqrt{\lambda_l} e_l^T \end{pmatrix} \quad (3.4)$$

The obtained solutions imply that the factor loadings matrix is chosen so that the individual factors are orthogonal to one another $\text{cov}(B_i B_j) = 0$ *for* $i \neq j$. The derived factors are extracted such that they explain part of the (shared) variance[124] in decreasing order. As a result the extracted factors are called principal component factors[125]. Since these loadings can be rotated without changing the obtained solution one still needs to decide which rotation to apply. The rotations are chosen in terms of interpretability of extracted factors, this is easiest if one gets relatively high or relatively low correlations among a factor and the observed variables. High loadings for certain variables indicate close relation with the underlying latent variable. As a rule of thumb component loadings of variables below 0.3 are to be considered insignificant whereas above 0.5 are considered highly significant.

As noted the rotational techniques are to help interpretability of the obtained solution, the two most common rotations used are varimax and oblimin. Varimax is

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[123] This can be tested using the KMO measure of sampling adequacy described further below.

[124] The proportion of the variance of X_j explained by the m common factors is defined as the communality, whereas the uniqueness is the opposite, that is the proportion of the variance of the variable that is not accounted for by the factor(s), uniqueness = 1 - communality

$$Comm(X_j) = \sum_{i=1}^{m} b_{ij}^2$$

[125] This is the standard technique used by the literature except for Stoneman and Battisti (2010) who use Iterative Principal Factor Analysis which is a slight variation in the sense that when the correlation matrix is analysed rather than assuming the communalities to be 1 it re-estimates them iteratively.

an orthogonal rotation that maximises the variance of the squared loadings of a factor on all the variables in a factor matrix. The advantage here is that it tends to "stick" to the "modelled" variables in the sense that it allows to relate variables to individual factors. Thus varimax stretches the loadings to their extremes (+1 or -1) improving interpretation of the factors without changing the model. Orthogonal rotations generate a loading matrix that shows the correlation between observed variables and factors. The other method that is not so often encountered is the oblimin rotation. This method minimizes across all pairs of axes, the sum of covariances of squared loadings. As opposed to varimax this allows for non-orthogonal (oblique) solutions, thus individual factors are allowed to be correlated and hence the results are often more interpretable due to its simpler structure then when applying an orthogonal rotation. For these the researcher has to choose the maximum amount of correlation allowed among the factors (determined by a coefficient gamma), standard procedures include quartimin (gamma is set 0, allowing for fairly high correlation), biquartimin (gamma is set to half) and covarimin, (gamma is set to 1 allowing for very high correlation)[126]. Unlike for orthogonal rotations for oblique rotations the obtained solution for B is called the pattern matrix. In this case the true correlation between variables and factors is only shown by the so called structure matrix. For interpretation generally the pattern matrix is used after oblique rotations. Both oblique and orthogonal rotations produce a factor score coefficient matrix. These allow predicting factor scores based on observed variables.

To assess whether it is sensible to carry out factor analysis in the first place the Kaise-Meyer-Olkin measure has been devised (Kaiser,1970). This takes values between 0 and 1 representing the variance among the variables that may be common variance. In other words it tells the researcher the extent to that the variables can be predicted by regression of each variable on all other variables. The reason why this should be very high is that the factor analysis relies on the eigenvalue decomposition of the correlation matrix. This is only feasible if the

[126] In this work a gamma value of 0 will be used. For the higher order factor analysis results using biquartimin, covarimin but also the standard orthogonal technique varimax will be presented in the appendix (3.7). These alternative rotational techniques have also been applied for the lower order factor analysis but have likewise led to factors with identical interpretations and thus these factor solutions will not be included here.

correlation matrix is diagnosable and the KMO is a measure to what extent this is possible and thus how valid it is to conduct factor analysis on the variables. Kaiser (1974) later categorised the values for this measure (KMO) as unacceptable for values between 0 and 0.49, miserable between 0.5 and 0.59, mediocre between 0.6 and 0.69, middling between 0.7 and 0.79, meritorious between 0.8 and 0.89 and marvellous between 0.9 and 1.

With respected to the number of factors to retain the only guideline used in the literature on modes of innovation is the Kaiser criterion. The Kaiser criterion suggests dropping the factors with eigenvalues smaller than 1. This means that factors that explain less variability than the "average" variable are dropped. Another complementary way to decide on a cut-off point is using the scree test, which however is ignored in the literature on modes of innovation. It involves plotting the number of retained factors versus the variance explained by the additional factor, at the point where the curve starts to "elbow" is the cut-off point for the number of factors to retain. So here the researcher in effect keeps the number of factors that explain a considerably larger part of the variability in the variables than the trend in explained variability of subsequent factors. Alternatively one could also keep as many factors as explain a certain percentage of the variation of the variables on which factor analysis is performed, in other words one ensures that the communality among factors is high[127]. Another aspect to consider when deciding on the number of factors to retain are the cross-loadings, if these are fairly high relative to the main loadings this may indicate another additional underlying factor. Though this is only applies when using orthogonal rotations. In confirmatory factor analysis interpretability of factors is used as a guide when choosing the number of factors to retain, this should be particularly considered when there are theoretical expectations about the types of factors to be identified. The approach that is followed here is that Kaiser criterion and the scree test should

[127] This is achieved by aiming for a low uniqueness of the variables in choosing the number of factors to retain. An approach that implies that one is interested in capturing variability of underlying variables rather then identifying actual latent variables that can be linked to theoretical conceptions. It also requires a rather arbitrary decision as to what size of communality to aim for. Due to potential measurement errors (of unknown size) as discussed in the previous chapter, as well as the survey potentially "ripping" into innovation strategy stages rather than fully capturing it there is expected to be a large amount of variability that will not be explained. Hence choice of factors to retain by communality does not seem ideal.

agree on the number of factors to retain and provide for a sensible theoretical interpretation of factors. If the two criteria do suggest a different number of factors to retain then the one that provides for the most convincing theoretical interpretation and is most consistent across the surveys will be chosen, while more weight is given to the Kaiser criterion following the literature on modes of innovation.

In the CIS some of the questions sets require respondents to make a subjective assessment of for instance their use of information sources for innovation which are rated on a scale of 0 to 3 (Likert scale), 0 for not being used and 1 to 3 indicating different degrees of importance of the variable. Other answers are simple dummy variables thus taking the values of 0 or 1. Kolenikov and Angeles (2004) point out that in this sort of situation the assumption necessary for valid factor analysis, that observed random variables are normally distributed is violated. To account for this a so called polychoric (or tetrachoric for binary data) correlation matrix of these variables should be used for factor analysis which is obtained under the assumption of underlying latent continuous normal variables. Though they show that ignoring the above tends to provide similar to more biased results, with the problem being less pronounced with large numbers of observations.

Let's now shortly describe the hierarchical approach[128] of factor analysis devised by Srholec and Verspagen (2008) to identify modes of innovation. It presents an alternative to using a "kitchen sink" style approach of including all available variables or arbitrarily select variables to include in a single factor analysis to identify modes of innovation. The hierarchical approach specified by Srholec and Verspagen (2008) involves in its first stage performing separate 'lower-order' factor analysis on the individual question sets using oblique rotations as these allow for latent variables to be correlated. Then in a second stage one performs factor analysis on the extracted factors to obtain a set of factors interpreted as 'higher-order factors'. While this may not represent accurately how innovation is carried

[128] Note that this is not equivalent to the "hierarchical factor analysis" which consists of factor analysis of identified factors obtained from all the questions rather than the factors obtained from subsets of the questions as done here. Though it is somewhat similar in its shortcomings, i.e. that it requires an interpretation based on an interpretation and means that parts of the variability in the factors is neglected in the second stage.

out it is supposed to overcome the, for this sort of analysis, somewhat arbitrary way the CIS questionnaire is designed. That is in terms of the choice of question sets themselves which have not been designed with subsequent factor analysis in mind and related to that the number of questions each one of the sets contains. As a result the survey design is likely to impose an unwanted structure to the factor analysis. That is when factor analysing all variables included in the survey it is likely to result in implausible innovation strategies. This happens because individual question sets are over-weighted because of the number of questions they contain and the resulting communality across them. Thus one obtains less sensible loadings as question sets tend to “stick” together identifying the common topic in these rather than actual innovation strategies. The hierarchical approach is to ensure that the latent variables of innovation contained in the CIS obtain a “fair” representation in the identified strategies of innovation.

Another advantage of this strategy is that it allows investigating the lower order factors in terms of their own theoretical interpretation[129]. This is relevant since the CIS survey rounds have as described seen considerable changes in their wordings and thus potential interpretation by respondents. This would show up using this approach. Also it allows one to see if the theoretical preconceived ideas from the theory of innovation can be confirmed or whether possibly the survey is lacking in capturing one or the other dimension previously identified in the literature. Finally note that no cluster analysis is performed subsequently on the identified modes. The reason is that the aim of this paper is not to group firms but to identify innovation strategies as applied by firms.

[129] This could potentially suggest redundant questions that could be dropped in order to include other “exploratory” questions. That means question sets that represent the same information content (loading strongly together) do not need to be included in the questionnaire and could be substituted for new “experimental” questions.

3.4. Data & Results

Table 3.1, Sample Sizes for Lower and Higher Order Factor Analysis

	CIS 4	CIS 5	CIS 6
Total (Product and process innovators)	5,636	4,462	4,083
Aims	5,628	2,888	3,574
Activities	5,636	4,457	3,893
Information	5,634	4,332	3,565
Cooperation	5,636	4,462	4,083
Higher Order 1	5,627	2,855	3,550
Protection	5,628	4,362	
Higher Order 2	5,621	2,837	
Support	5,628		3,684
Higher Order 3	5,620		3,500
Wider	5,628	4,415	3,875
Higher Order 4	5,620	2,854	3,550
Barriers	5,630	4,406	3,722

The factor analysis to identify modes of innovation is only carried out for those firms that have had innovative outputs. It would have been preferable to include all firms undertaking innovative activities, that is including those that had ongoing and abandoned activities as well since they must have an innovation strategy in place, too. The reason why the analysis of the modes of innovation is limited to those with innovative output is twofold, on the one hand innovation strategies are to be identified for innovative firms only and there are firms that have no scope for innovation and thus have no innovative strategy in place, so including them would not be useful. The second reason for limiting the analysis to observations with innovative outputs is a result of one of the aims of this thesis being to compare the different CIS survey rounds. This restricts the data to be used to the smallest "common ground" among the innovation surveys which is defined by the question about 'determining factors for innovation'[130] in the CIS 5 which is only asked to firms that have had product or process innovations introduced during the survey

[130] q1210-1290. Termed "effects of innovation" in the CIS 4.

period. The wording is not exactly to the same effect referring to: “did this business undertake any product or process innovations”. Since there was no equivalent group in the other samples it had to be restricted to firms that actually introduced product and process innovations, also see tables (2.26 – 2.28). This reduces the sample size for the factor analysis of ‘determining factors for innovation’ for the CIS 5 and thus the final higher order factor analysis quite considerably (see table 3.1). Results presented in the next section are however very similar for the lower order factor analysis of ‘determining factors for innovation’ across the surveys despite this imperfect match of respondent groups.

Table 3.2, Question sets used for lower order factor analysis

Question set (coded)	CIS	Information content
q1210-q1290 (0-3)	4, 5, 6	importance of effects of innovation *different groups addressed* *(innovated, deciding to innovate, deciding to innovate)*
q1310-q1370 (0,1)	4, 5, 6	innovative activities, inputs
q1601-q1611 (0-3)	4, 5, 6	importance of information sources for innovation
q1810-q1870 (0,1)	4, 5, 6	cooperation partners used for innovation *constructed ignoring geographic distance of partner* *coded 1 if partner existed at any geographic distance*
q1901-q1911 (0-3)	4, 5, 6	barriers to innovation experienced **-not included in higher order factor analysis** *differing groups addressed* *(all, reason for not, innovation active only)*
q2110-q2180 (0-3)	4, 5	Importance of protection methods for innovation **-separately included in higher order factor analysis**
q2210,20,40 (0,1)	4, 6	financial public support received for innovation **-separately included in higher order factor analysis** *devolved moves from q2220 to q2210*
q2310-q2340 (0,1)	4, 5, 6	wider forms of innovation introduced **-separately included in higher order factor analysis**

Not all of the question sets contained in the survey are included or included immediately in the higher order factor analysis as some of them have substantially changed over the different surveys, were not included in each survey round or it is not clear whether they can actually be considered part of the innovation strategy[131] (see table 3.2). Specifically the question set on 'barriers to innovation' is not included in the higher order factor analysis, since in the CIS 4 it relates to "constraints to your innovation activities or influencing a decision not to innovate" while in the CIS 5 it is about "constraints on innovation activities in influencing a decision not to innovate" and in the CIS 6 about factors "constraining innovation activities". There is another reason for not including it in the higher order factor analysis though. The treatment of barriers of innovation is not part of mainstream innovation theory and is rather a concept that has arisen out of the notion that removal of barriers helps innovation, thus there is no direct reason to interpret it as part of an innovation strategy or regime[132]. The information on the 'importance of protection methods' is only available in the CIS 4 and the CIS 5 and information on the 'receipt of public support' only in the CIS 4 and the CIS 6. Thus higher order factor analysis where the lower order factors based on these question sets are included are presented separately for the datasets in which this information is present. Likewise the information on wider forms of innovation are tentatively included as for one there is no clear consensus in the literature whether this should be interpreted as an output or an input[133] and secondly it is not clear as explained in the previous chapter whether these questions have been sufficiently well defined and are well enough connected to the rest of the more technology oriented CIS survey. A last caveat is that the number of questions in each question set has sometimes been increased over the surveys where individual sub-options were split into two, in this case the scores were added up to recreate the original sub-option and the polychoric correlation matrix is based on these added up scores[134]. Though

[131]Notably there is no literature suggesting that firm characteristics (thought of as more permanent) or innovative outputs directly influence the innovation strategy or regime and thus these variables are not included.
[132] Similarly none of the reviewed papers on innovation modes has included it in their analysis.
[133] It is seen as complement or even precondition to technological innovation (Bloom and Van Reenen, 2007; Edwards, Battisti and Neely, 2004; Lam, 2005) but has also been interpreted as innovation in its own right (OECD and Eurostat, 2005).
[134] This is the case for 'importance of effects of innovation', here starting with the CIS 6 the question about 'entering new markets' or 'increasing market share' was split. Also the question about 'reducing environmental impacts' or 'improving health and safety' was split.

this was not done for the question about innovative inputs[135] since it is not based on subjective assessment but related to whether an activity was undertaken or not. These have thus been recoded. If one of these subcomponents has been positively answered it is interpreted as positively answering the whole question.

3.5. Results

As noted the extraction, description and interpretation of the lower order factors have due to their length been deferred to the appendix (section 3.7) of this chapter. The following lower order factors have been identified. Two lower order factors were found for the question set about 'effects of innovation', one of them has strong loadings of factors important for process innovation and the other for factors related to product innovations, thus they were termed "process aim" and "product aim" respectively. For the questions relating to the 'innovative activities undertaken' a single factor has been identified. Factor analysis of the question set regarding the 'sources of information used for innovative activities' lead to a two factor solution. One factor with strong loadings of sources of information from the market including suppliers, competitors and customers, thus it was named "market sources". The second factor has strong loadings of the information from specialized sources including HE and public research institutes. It was thus called "science sources". The factor analysis of all other question sets including the use of 'appropriation methods', 'cooperation partners' used, 'wider forms of innovation' undertaken and the receipt of 'public support' lead to the extraction of a single lower order factor. Only the question about 'barriers to innovation' lead to the extraction of three lower order factors which are however as noted previously not used in the higher order factor analysis.

[135] The question on 'acquisition of machinery, equipment and software for innovation' starting with the CIS 5 is split into the three individual components 'advanced machinery', 'computer hardware' and 'computer software'. In the same question set the question about 'market introduction of innovations' has been divided into three starting with the CIS 5, these are 'changes to product or service design', 'market research' and 'changes to marketing methods'.

Table 3.3, Higher Order Factor analysis, CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.67	0.03		0.54	0.80
Product Aim	0.79	-0.21		0.40	0.73
Inputs	0.47	0.36		0.58	0.82
Science Sources	0.43	0.52		0.45	0.73
Market Sources	0.78	0.08		0.36	0.74
Cooperation	-0.07	0.89		0.22	0.73
			next factor		
Eigenvalues (1st, 2nd, ...)	2.44	1.00	0.79		
Explained variability					
before rotation	0.41	0.17	0.13		
after rotation	0.38	0.24		Total KMO	0.76

Table 3.4, Higher Order Factor Analysis, CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.68	0.06		0.52	0.81
Product Aim	0.75	-0.21		0.46	0.76
Inputs	0.41	0.51		0.47	0.79
Science Sources	0.45	0.51		0.44	0.75
Market Sources	0.76	0.05		0.40	0.75
Cooperation	-0.11	0.88		0.25	0.72
			next factor		
Eigenvalues (1st, 2nd, ...)	2.42	1.03	0.75		
Explained variability					
before rotation	0.40	0.17	0.12		
after rotation	0.36	0.26		Total KMO	0.76

Table 3.5, Higher Order Factor Analysis, CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.64	0.08		0.56	0.77
Product Aim	0.83	-0.15		0.34	0.72
Inputs	0.30	0.47		0.62	0.79
Science Sources	0.37	0.57		0.44	0.74
Market Sources	0.70	0.13		0.45	0.76
Cooperation	-0.11	0.89		0.24	0.73
			next factor		
Eigenvalues (1st, 2nd, ...)	2.36	1.01	0.81		
Explained variability					
before rotation	0.39	0.17	0.13		
after rotation	0.34	0.27		Total KMO	0.75

Figure 3.2, Scree plot Higher Order Factor Analysis CIS 4

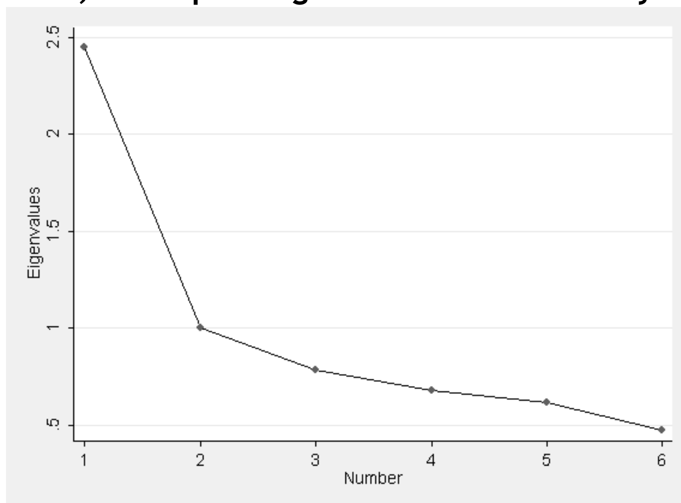


Figure 3.3, Scree plot Higher Order Factor Analysis CIS 5

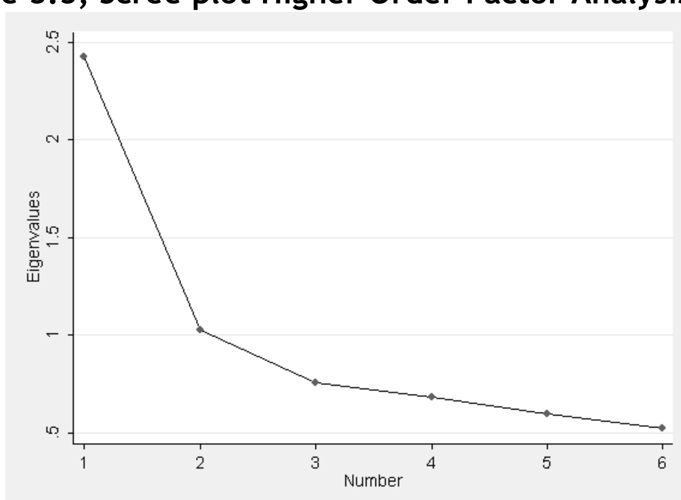
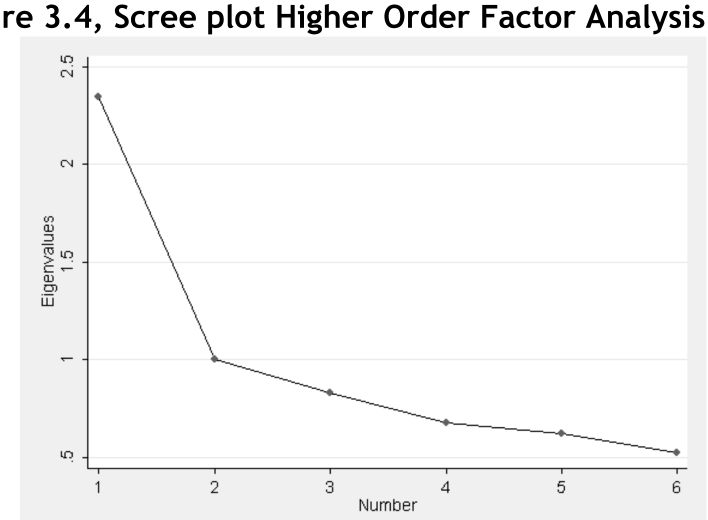


Figure 3.4, Scree plot Higher Order Factor Analysis CIS 6



In the higher order factor analysis[136] two factors are identified with eigenvalues larger then 1 (Kaiser criterion) which explain between 56 and 58% of the variability of the lower order factors (table 3.3 – 3.5), while according to the scree plots (figures 3.2 – 3.4) one, two or a three factor solution can be identified.[137] Since generally a smaller number of lower order factors is retained then in the work of Srholec and Verspagen (2008) as expected also less higher order factors are identified and their four factor solution can thus not be compared with the results here. The first mode of innovation identified features both 'aims of process innovation' as well as 'aims of product innovation'. It also has a strong loading of 'inputs to innovation' as well as 'information from science sources' but more importantly 'information from market sources'. The 'use of protection methods' if included (tables 3.36 and 3.37) also loads strongly on this factor. 'Wider forms of innovation' if included load to a weaker degree (tables 3.53 - 3.55) if included. This first higher order factor explains between 34 and 38% of the variability of the lower order factors. The second mode of innovation that has been found also features intermediate loading of 'innovative inputs' and information from 'science sources' as well as a very strong loading of 'cooperation partners used'. The lower order factors 'public support' (tables 3.58 and 3.59) and 'wider forms of innovation' (tables 3.53 - 3.55) also load on this factor if included. It explains between 24 and 27% of the variability of the lower order factors.

[136] Results of different type of rotational techniques are presented in appendix 3.7, these are almost identical.
[137] A similar solution is obtained when retaining three lower order factors for the aims of innovation (table 3.19 – 3. 21) presented in the appendix (3.6). As pointed out in the appendix dealing with the lower order factor extraction (3.6) this solution was discarded as it did not affect the higher order factor solutions (all of the lower order factors loaded strongly on the same higher order factor solution) and it was felt only a two factor solution could be justified on theoretical grounds.

Table 3.6, Higher Order Factor Analysis with Appropriation, CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.65	-0.03		0.58	0.84
Product Aim	0.78	-0.25		0.42	0.78
Inputs	0.49	0.33		0.58	0.85
Science Sources	0.46	0.48		0.46	0.78
Market Sources	0.77	0.03		0.39	0.80
Cooperation	-0.05	0.88		0.24	0.79
Protection	0.60	0.24		0.52	0.83
			next factor		
Eigenvalues (1st, 2nd, …)	2.82	1.00	0.80		
Explained variability					
before rotation	0.40	0.14	0.11		
after rotation	0.38	0.21		Total KMO	0.81

Table 3.7, Higher Order Factor Analysis with Appropriation, CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.66	0.04		0.55	0.83
Product Aim	0.76	-0.19		0.46	0.80
Inputs	0.34	0.55		0.48	0.83
Science Sources	0.39	0.56		0.42	0.79
Market Sources	0.74	0.07		0.42	0.81
Cooperation	-0.19	0.85		0.33	0.78
Protection	0.44	0.46		0.50	0.81
			next factor		
Eigenvalues (1st, 2nd, …)	2.80	1.03	0.77		
Explained variability					
before rotation	0.40	0.15	0.11		
after rotation	0.34	0.27		Total KMO	0.81

Figure 3.5, Scree plot Higher Order Factor Analysis with Appropriation CIS 4

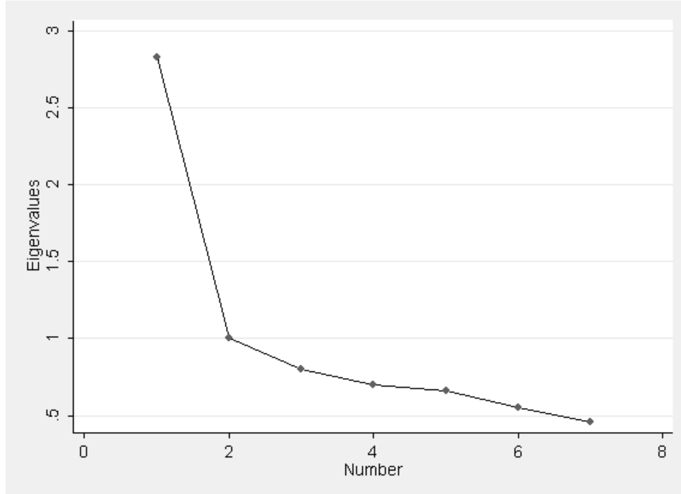


Figure 3.6, Scree plot Higher Order Factor Analysis with Appropriation CIS 5

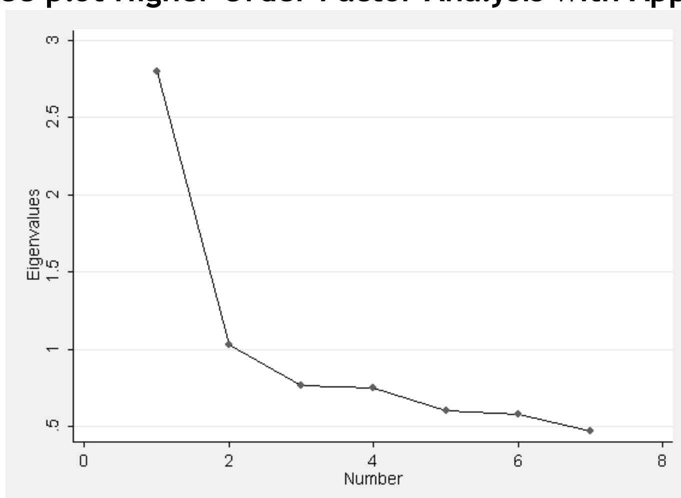


Table 3.8, Higher Order Factor Analysis with Wider Innovation, CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.69	-0.02		0.53	0.83
Product Aim	0.78	-0.18		0.42	0.76
Inputs	0.45	0.39		0.57	0.84
Science Sources	0.43	0.47		0.50	0.77
Market Sources	0.77	0.07		0.38	0.77
Cooperation	-0.10	0.87		0.27	0.78
Wider Innovation	0.34	0.45		0.61	0.84
			next factor		
Eigenvalues (1st, 2nd, ...)	2.69	1.01	0.83		
Explained variability					
before rotation	0.38	0.14	0.12		
after rotation	0.34	0.23		Total KMO	0.80

Table 3.9, Higher Order Factor Analysis with Wider Innovation, CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.67	0.06		0.52	0.83
Product Aim	0.75	-0.17		0.47	0.79
Inputs	0.37	0.53		0.48	0.81
Science Sources	0.43	0.48		0.49	0.79
Market Sources	0.76	0.05		0.41	0.78
Cooperation	-0.16	0.85		0.32	0.76
Wider Innovation	0.22	0.51		0.63	0.85
			next factor		
Eigenvalues (1st, 2nd, ...)	2.63	1.05	0.79		
Explained variability					
before rotation	0.38	0.15	0.11		
after rotation	0.32	0.26		Total KMO	0.80

Table 3.10, Higher Order Factor Analysis with Wider Innovation, CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.70	-0.02		0.51	0.79
Product Aim	0.80	-0.08		0.40	0.74
Inputs	0.16	0.60		0.55	0.79
Science Sources	0.39	0.47		0.52	0.76
Market Sources	0.70	0.11		0.45	0.78
Cooperation	-0.13	0.79		0.42	0.76
Wider Innovation	0.04	0.60		0.63	0.81
			next factor		
Eigenvalues (1st, 2nd, ...)	2.51	1.03	0.91		
Explained variability					
before rotation	0.36	0.15	0.13		
after rotation	0.30	0.27		Total KMO	0.78

Figure 3.7, Scree plot Higher Order Factor Analysis with Wider Innovation CIS 4

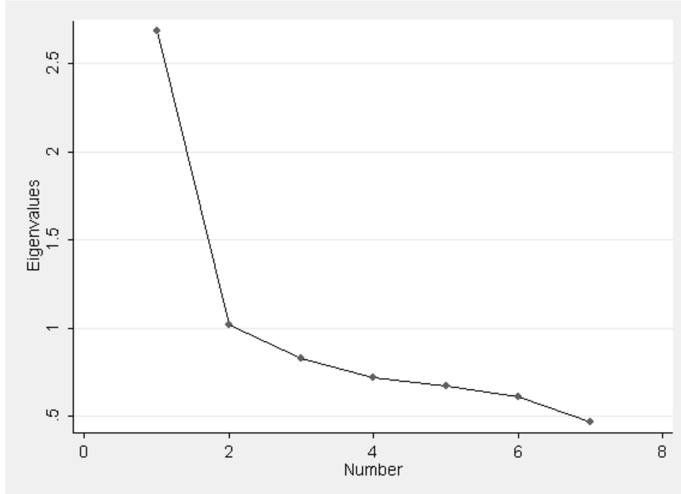


Figure 3.8, Scree plot Higher Order Factor Analysis with Wider Innovation CIS 5

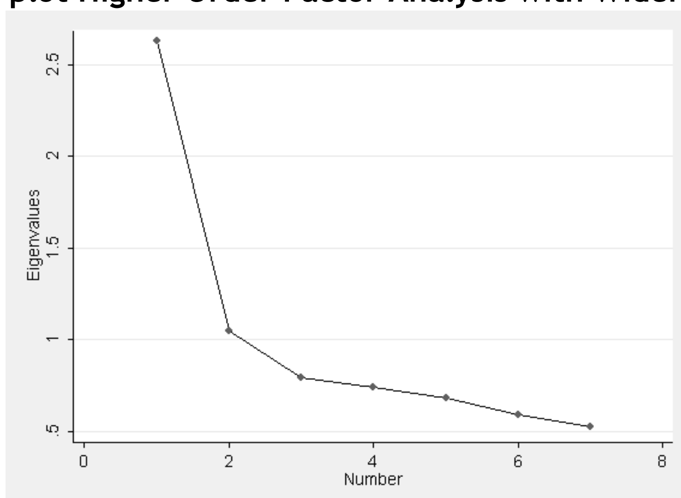


Figure 3.9, Scree plot Higher Order Factor Analysis with Wider Innovation CIS 6

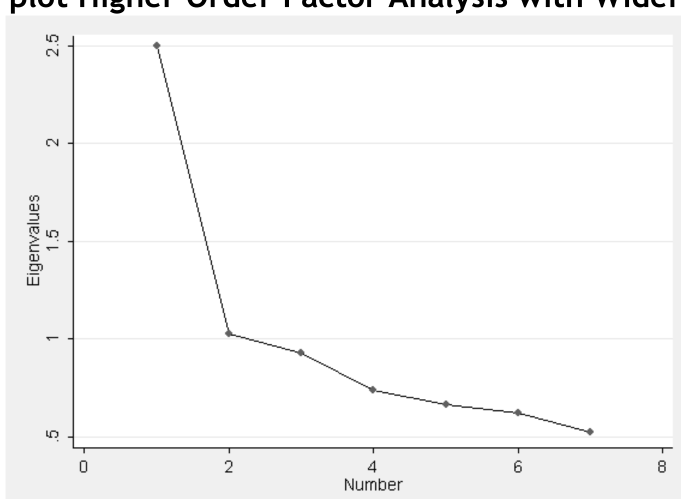


Table 3.11, Higher Order Factor Analysis with Support, CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.72	-0.09		0.50	0.80
Product Aim	0.72	-0.11		0.51	0.74
Inputs	0.48	0.35		0.57	0.83
Science Sources	0.52	0.36		0.51	0.75
Market Sources	0.80	0.01		0.36	0.74
Cooperation	0.03	0.74		0.45	0.75
Government Support	-0.09	0.74		0.47	0.74
			next factor		
Eigenvalues (1st, 2nd, …)	2.51	1.11	0.86		
Explained variability					
before rotation	0.36	0.16	0.12		
after rotation	0.33	0.22		Total KMO	0.77

Table 3.12, Higher Order Factor Analysis with Support, CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.70	-0.07		0.52	0.77
Product Aim	0.74	-0.11		0.48	0.72
Inputs	0.38	0.44		0.61	0.79
Science Sources	0.54	0.39		0.48	0.75
Market Sources	0.74	0.02		0.45	0.76
Cooperation	0.17	0.66		0.50	0.74
Government Support	-0.21	0.75		0.45	0.67
			next factor		
Eigenvalues (1st, 2nd, …)	2.39	1.13	0.88		
Explained variability					
before rotation	0.34	0.16	0.13		
after rotation	0.31	0.22		Total KMO	0.74

Figure 3.10, Scree plot Higher Order Factor Analysis with Public Support CIS 4

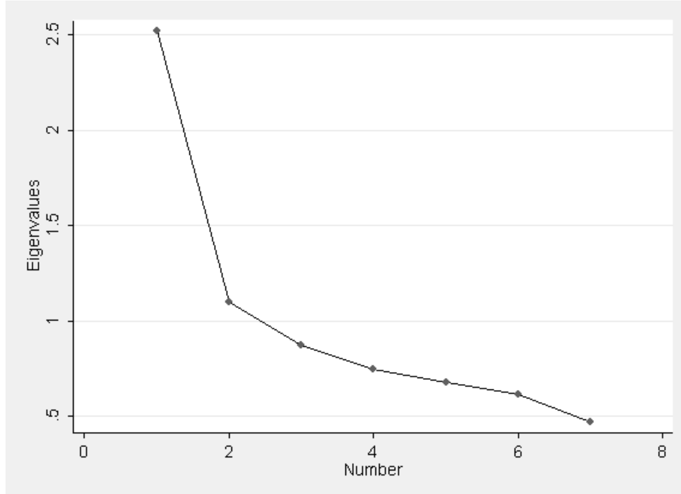
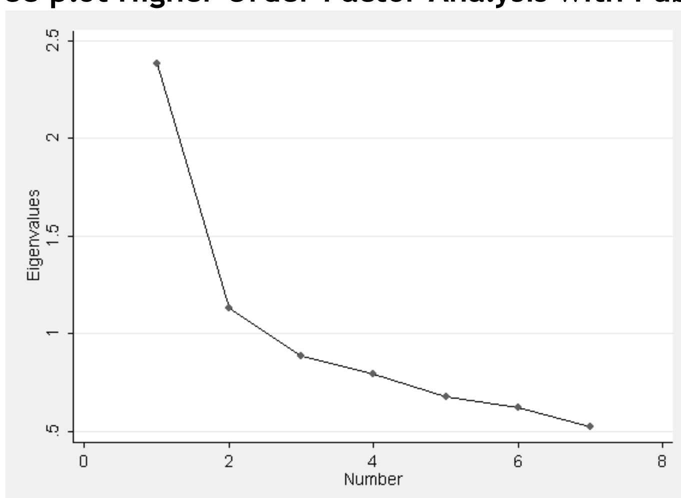


Figure 3.11, Scree plot Higher Order Factor Analysis with Public Support CIS 6



An interpretation of these factors is now undertaken. The first identified factor represents a strategy of innovation aimed at direct outputs in the form of product and process innovations relying on innovative inputs while also making use of information from science sources it relies more strongly on information from market sources. It hence is related to the classical perspective of innovation as an input output relationship and thus has been termed "traditional" or "linear" innovation mode. The second identified factor has no direct aim as such, at least none that can be identified according to the information contained in the CIS. However since it involves the 'science sources' lower order factor and the use of 'innovative inputs' and 'cooperation' as well as 'public support' and 'wider forms of innovation' if included it is a strategy based on knowledge generation by firms involving organisational aspects. These sorts of activities are linked to the so called "dynamic capabilities" of a firm, which are important for keeping abreast of developments in the market potentially by sharing pre-competitive research costs and drawing on public support aimed at this kind of knowledge enhancing activity. It has therefore been termed "dynamic". In a similar vein Makadok (2001) distinguishes dynamic capabilities from resources and argues that these are not necessarily complementary. That is while specific innovation inputs and sources of information allow for distinct firm capabilities this is not necessarily related to search activities that allow firms to keep abreast of developments in the economy. Overall these findings can also be likened to those by Jensen et al. (2007). Their 'Doing and Using' innovation mode involves experience based innovation through acquisition of tacit knowledge and considering user needs which the "linear" mode identified here is similar to in that it has the introduction of products and process as its aim while strongly depending on information from market sources. Whereas the 'Science and Technology' innovation mode that involves the production and use of codified scientific knowledge is comparable to the "dynamic" mode for which the use of science sources of information and cooperation are important. A related dichotomy is found in the work of Zi-Lin and Poh-Kam (2004) who for organizational learning distinguishe among 'exploration' comparable to what is the "dynamic" mode without specific aims (blue skies) and 'exploitation' which is linked to the "traditional" mode aiming to commercialize knowledge.

Looking at the details of the lower order factor analysis while some differences across surveys have been identified they are by and large very similar. At the same time some pre-existing notions about innovation if the study is to be interpreted as exploratory cannot be necessarily confirmed based on the correlations, that is often complementary rather than substitutability of variables is identified, further strengthening the choice of applying orthogonal rotations. Nevertheless the final higher order two factor solution has shown quite robust to over-extraction of factors in the spirit of a confirmatory analysis (so number of lower order factors to retain being determined by theory), that is retaining more factors then initially identified. The “linear” and “dynamic” modes thus emerge as a fundamental feature of innovative activities as captured by the CIS survey.

3.5. Conclusion

This chapter contains in Appendix 3.8 a discussion of the importance of appropriation and absorptive capacity in relation to knowledge spillovers and thus innovation and explains how the former two have been measured using firm level data. The results of the factor analysis on the individual question sets available in the CIS considered to represent absorptive capacity and appropriation are presented in Appendix 3.9 creating a measure of absorptive capacity and a measure of appropriation which are to be used as explanatory variables in the following two chapters. While the literature argues that absorptive capacity can be divided into actual and realized absorptive capacity based on the information available from the CIS[138] on theoretical grounds only allows one generic measure of absorptive capacity to be generated. In this sense the factor analysis was confirmatory. That is a two factor solution could not be interpreted as reflecting a distinction among realized and actual absorptive capacity. It has been argued that it is the only way to measure absorptive capacity for the UK CIS without having to rely on linking information across surveys to obtain information about past innovative activities and thus have to work with a much reduced data set. Also measures relying on R&D spending ignore other innovative inputs particularly important for the services and smaller firms thus measures based on past R&D are likely to be biased. Regarding

[138] The rating of the importance of source of information for innovation.

the appropriability measure identified, while the past literature has found that there are diversified appropriation strategies that are used by firms a single factor has been identified which captures the largest part of the variability of the rating of importance of appropriation measured by firms present in the CIS suggesting that formal and informal methods of appropriation are indeed complementary (Teece, 1986), in this sense the factor analysis was exploratory. While the approach is identical to that taken for generating the absorptive capacity measure no previous studies based on the CIS have made use of such a measure for it.

This chapter was to further extend the analysis of the UK CIS using factor analysis. The literature investigating the modes of innovation based on firm level surveys has been detailed in this chapter together with its varied theoretical underpinnings. The subsequent section described how factor analysis is carried out. To identify modes of innovation a hierarchical procedure of factor analysis using oblique rotations has been followed so as not to a priory have to arbitrarily discern certain parts of the information contained in the CIS. This meant first finding lower order factors based on the individual question sets. The use of oblique rotational techniques is justified on the basis of the overlap among the factors that were found. With notable exception of the factors derived from the 'effects influencing a decision to innovate' which have a few variables loading differently for the CIS 6, very similar lower order factors have emerged across the surveys. Thus while the previous chapter has shown considerable differences in the mean responses to questions, identifying similar factors lends support to the idea that more permanent latent variables drive the responses to these questions. These lower order factors were then compared with existing conceptions about the nature of innovation and according to the results the properties and activities of firms are of more complementary nature then the innovation literature previously has suggested, nevertheless the results confirm the theoretical conceptions on which these surveys are built. The generated lower order modes were then used in a subsequent factor analysis to generate the higher order modes. As a result two higher order innovation strategies were found. This is different to the 4 factor solution identified by Srholec and Verspagen (2008) whose methodology has been followed herein but whose analysis relied on the CIS 3 data from 13 European countries excluding the UK. One has been dubbed “traditional” or “linear” since it is aimed at process and product innovation distinctly driven by information from the market making use of innovative inputs. The second was termed “dynamic” making use of innovative inputs as well as relying on cooperation and information from the science base as well as its market. Since this strategy is not directly aimed at generating innovative output but related to the use of source of information as well as innovative inputs it is interpreted to reflect the firms dynamic capabilities which “integrate, build and reconfigure internal and external competences” (Barreto, 2010) in order to be able to keep abreast of developments in quickly changing environments. The findings compared to those of Srholec and Verspagen (2008) imply that lower order innovation modes are of more complementary nature when looked at from a country wide(UK) perspective. They also allow for an interpretation that can be directly linked to theoretical conceptions of the innovation literature.

There are some limitations to the results of this chapter which are discussed next. The generated measures of absorptive capacity as well as the appropriation measure are likely to be imperfect proxies. If a firm does not use information from certain sources for its innovative activities this does not necessarily imply it does not have the right resources to make use of them, nonetheless retaining a single measure of absorptive capacity makes this less of an issue. However rating information sources for innovative activities as important may simply indicate that innovative efforts are present and thus (to a lesser degree though) innovative outputs making this sort of measure of absorptive capacity potentially endogenous if used in subsequent regression analysis explaining these two dimensions. That is one may only get to measure “absorptive capacity” as done here for firms when they carry out ‘innovative activities’ and potentially generate innovative outputs. This criticism does not apply so much for the ‘appropriation’ measure since here the firms are simply asked to evaluate how important appropriation methods are for their innovations. It is hence more dependent on past rather than present innovative activity. The absorptive capacity measure on the other hand can be defended on grounds of the relative persistence of innovative activities and related to that the need for using absorptive capacity on a continual basis. In any case despite its potential endogeneity research making use of this information (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011) likewise assumed it exogenous to innovative activities. With respect to sources of information it has gone even further and used this information for firms with innovative outputs only (Lööf and Heshmati, 2002; Griffith et al. 2006; Raffo et al. 2008). The main reason for this is that for most other countries CIS surveys this question has only been directed at those with innovative outputs (or the innovation active) as in the CIS 6. This is likely to make a measure of absorptive capacity more endogenous and is a major reason why the derived variable was not created for the CIS 6. Indeed Lhuillery (2011) confirms use of information from innovation active firms only results in overestimation of its effect because knowledge from competitors may indeed deter firms from innovating. From a theoretical standpoint it can be argued that measures such as obtained by Camison and Fores (2010) using firm's self-assessment about their performance relative to competitors in terms of acquisition, assimilation, transformation and application of knowledge or as used by Jansen et al. (2005) regarding coordination capabilities and socialization capabilities are less prone to the above criticism and more closely related a firm's absorptive capacity. Hence their inclusion in the CIS or at least an investigation of their relationship to absorptive capacity measure generated here should be considered.

Factor analysis relies on an extensive question set including all the dimensions sought after. However any survey specifically so the CIS is collected with some preconceived ideas about the matter at hand, in this case innovation as defined in the Oslo manual which is quite prescriptive about the matter. As such it may not provide the best sort of data for an exploratory factor analysis. This is particularly true for organisational and service innovation whose aspects as argued in the previous chapter are not adequately covered in the CIS and which have been shown important in determining a firm's absorptive capacity (Jansen et al., 2005; Schmidt, 2010). Nonetheless the line between exploratory and confirmatory analysis is always blurred in reality. Ideally one should have a dialogue between designing the survey and investigating what it tells us without compromising the element of comparability of survey rounds too much.

Another criticism of factor analysis is that it only identifies correlations which do not imply causality. This is a problem generally inherent in cross sectional analysis and it is for this reason that the relations that are looked are interpreted in light of innovation theory. What also becomes clear in this work is that the cut-off criterion for the number of factors to retain and the interpretation of resulting factor solutions is no exact science and somewhat haphazard in nature, often depending on what populations one looks at which in turn is limited by the survey design itself. This fact and the differing choices in terms of variables included by previous researchers have meant that the modes identified by this work are quite distinct. The variability caused by differences in the survey designs across countries as well as their underlying systemic differences is likely to further explain why less innovation strategies and less lower order factors than in Srholec and Verspagen's (2008) work have been found. Like in other similar studies a large amount of variability in the question sets was left unaccounted for by the factors. This observed randomness fits well though with the previously noted heterogeneity of firms. At the same time the identified modes also leave room for heterogeneity in terms of the nature in that for instance intramural R&D was carried out or in terms of the way cooperation was undertaken. Another reason for the unexplained heterogeneity though may have been that the survey rips into the innovation cycle of some firms[139] and thus the existing correlations are lost. Support for this argument is found when analysing innovative inputs based on the information about the spending in the last year of the survey which leads to more identified factors then when using the information provided for innovative inputs carried out during the whole survey period. Thus the time period within which one analyses the matter is important. While in the long run innovative activities and aims are likely to turn complementary and thus fewer factors can be identified in the short run activities and aims are likely to be of more substitute nature in line with economic thinking.

[139] This is inherent to the subject type approach, however it is difficult to identify an innovation process cycle in the first place.

3.6. Appendix – Lower Order Factor Analysis

Effects of Innovation

The correlation matrix for ‘determining factors for innovation’ (tables 3.13 – 3.15) indicates a high correlation in the ranking of the aim to increase the ‘capacity of production’ and to have ‘flexible production’. The other two areas with fairly high correlation are ‘entering new markets’/’increasing the market share’ and ‘increased range’ (not for the CIS6 though) as well as ‘regulatory requirements’, ‘environmental’/’health and safety’. The first of these correlations indicates that considerations of capacity and flexibility of production are related. It is also somewhat expected that an increased range through diversification allows firms to increase their market share and enter new markets thus these aims are more congruent then the other ones. The fact that the aim to meet ‘regulatory requirements’ correlates with the aim to decrease ‘environmental impacts’ and improve ‘health and safety’ suggests that at least part of the improvements which go towards the later aim may be driven by policy or that policy changes drive innovation through influencing environmental or health and safety standards. All correlations are positive implying that none of the aims are conflicting with one another. Overall the CIS 4 and CIS 5 correlations look fairly similar. However there are some considerable differences among them and the correlations observed in the CIS 6. Specifically the correlation among ‘new markets’/’increased market share’ and ‘increased range’ has become small and so has the correlation among ‘regulatory requirements’ and ‘increased value added’. The first difference is likely to be due to the question on ‘increasing market share’/’entering new markets’ being split into two. The correlation among these two is fairly low at 0.41 thus providing support for the split. There is no obvious reason for the second observed difference except for a change in regulation with respect to the requirements for value added, or increased regulatory requirements unrelated to value added.

Table 3.13, Correlation Matrix Effects of Innovation, CIS4

	Increased range	New mkts / mkt share	Improved quality	Flexibility of production	Capacity of production	Lower cost of production	Environment /health & safety	Regulatory	Increased value added
Increased range									
New markets / market share	0.57								
Improved quality	0.37	0.38							
Flexibility of production	0.25	0.31	0.53						
Capacity of production	0.21	0.31	0.43	0.72					
Lower cost of production	0.23	0.33	0.41	0.54	0.55				
Environment/health & safety	0.17	0.20	0.43	0.44	0.43	0.53			
Regulatory requirements	0.21	0.22	0.39	0.35	0.32	0.39	0.65		
Increased value added	0.42	0.46	0.53	0.42	0.39	0.44	0.38	0.43	

Table 3.14, Correlation Matrix Effects of Innovation,CIS5

	Increased range	New mkts / mkt share	Improved quality	Flexibility of production	Capacity of production	Lower cost of production	Environment /health & safety	Regulatory	Increased value added
Increased range									
New markets / market share	0.58								
Improved quality	0.34	0.39							
Flexibility of production	0.24	0.28	0.55						
Capacity of production	0.19	0.28	0.49	0.71					
Lower cost of production	0.16	0.26	0.40	0.51	0.56				
Environment/health & safety	0.23	0.26	0.45	0.42	0.43	0.55			
Regulatory requirements	0.22	0.24	0.42	0.36	0.36	0.40	0.66		
Increased value added	0.41	0.47	0.52	0.45	0.39	0.45	0.41	0.44	

Table 3.15, Correlation Matrix Effects of Innovation,CIS6

	Increased range	New mkts / mkt share	Improved quality	Flexibility of production	Capacity of production	Lower cost of production	Environment /health & safety	Regulatory	Increased value added
Increased range									
New markets / market share	0.40								
Improved quality	0.27	0.26							
Flexibility of production	0.31	0.28	0.47						
Capacity of production	0.24	0.26	0.35	0.69					
Lower cost of production	0.15	0.26	0.29	0.45	0.49				
Environment/health & safety	0.13	0.24	0.35	0.34	0.37	0.49			
Regulatory requirements	0.16	0.23	0.32	0.30	0.28	0.37	0.68		
Increased value added	0.32	0.37	0.49	0.42	0.42	0.39	0.33	0.26	

Table 3.16, Factor Analysis Effects of Innovation, CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Increased range	-0.07	0.88		0.26	0.80
New markets / market share	0.03	0.84		0.28	0.82
Improved quality	0.52	0.40		0.42	0.90
Flexibility of production	0.73	0.12		0.38	0.82
Capacity of production	0.73	0.08		0.41	0.82
Lower cost of production	0.75	0.07		0.40	0.91
Environmental / health & safety	0.88	-0.18		0.32	0.80
Regulatory requirements	0.76	-0.08		0.47	0.80
Increased value added	0.43	0.50		0.40	0.90
			next factor		
Eigenvalues (1st, 2nd, …)	4.38	1.28	0.90		
Explained variability					
before rotation	0.49	0.14	0.10		
after rotation	0.44	0.30		Total KMO	0.84

Table 3.17, Factor Analysis Effects of Innovation, CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Increased range	-0.02	0.85		0.30	0.85
New markets / market share	-0.05	0.88		0.26	0.82
Improved quality	0.52	0.38		0.41	0.91
Flexibility of production	0.72	0.12		0.40	0.85
Capacity of production	0.78	0.01		0.39	0.84
Lower cost of production	0.79	-0.03		0.40	0.89
Environmental / health & safety	0.83	-0.07		0.35	0.81
Regulatory requirements	0.78	-0.06		0.44	0.82
Increased value added	0.39	0.53		0.38	0.89
			next factor		
Eigenvalues (1st, 2nd, …)	4.51	1.17	0.89		
Explained variability					
before rotation	0.50	0.13	0.10		
after rotation	0.46	0.33		Total KMO	0.85

Table 3.18, Factor Analysis Effects of Innovation, CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Increased range	0.79	-0.27		0.45	0.83
New markets / market share	0.68	-0.06		0.56	0.85
Improved quality	0.53	0.25		0.56	0.86
Flexibility of production	0.60	0.31		0.42	0.79
Capacity of production	0.52	0.36		0.47	0.80
Lower cost of production	0.24	0.60		0.47	0.90
Environmental / health & safety	-0.01	0.88		0.24	0.76
Regulatory requirements	-0.05	0.83		0.33	0.74
Increased value added	0.66	0.17		0.47	0.88
			next factor		
Eigenvalues (1st, 2nd, …)	3.99	1.18	0.94		
Explained variability					
before rotation	0.44	0.13	0.10		
after rotation	0.36	0.33		Total KMO	0.82

The factor analysis leads to two factors with eigenvalues greater than 1 being identified (tables 3.16 – 3.18). On the other hand the scree test (figures 3.12 – 3.14) suggests to retain three factors according to the CIS 4 and the CIS 5 and one or three according to the CIS 6 data. For the two factor solution one is centred on effects related to the production process and the other on effects related to the product. That is the first factor suggests that firms aim to 'improve flexibility', 'increase capacity' and 'lower costs' as well as try to 'improve environmental aspects or improve health and safety' of their products/production while 'meeting regulatory requirements' together, hence this factor is interpreted as "effects of process innovation". 'Increased value added' and 'improved quality' are important for both factors. The other two aims that load strongly for the second factor are to 'increase the range' and 'enter new markets or increase the market share' and it is thus interpreted as "effects of product innovation". For the CIS 6 the order of the factors has changed and also somewhat their loadings. 'Improved quality', 'flexibility' and 'capacity of production' now load more strongly with second factor "effects of product innovation". The results confirm that process and product innovations are distinct in their own right when considered by firms in terms of their effects. The observed differences among the surveys here can already be identified when looking at the proportion of firms ranking 'effects of innovation as important' (tables 2.26 – 2.28). An additional factor included as suggested by the scree test (Figures 3.12 – 3.14) reflects 'reduced environmental impact and improved health and safety' and 'regulatory requirements'. This is also the number and type of factors that Srholec and Verspagen (2008) identify in their cross country analysis. This emerging factor is evidence that 'policy' and 'environmental, health and safety' aspects are increasingly important in shaping the innovation landscape. The two factor solution is retained here, for one because in either case the aims factors load strongly on the "linear"/ "traditional" higher order factor (see table 3.69 – 3.71). Secondly from a theoretical standpoint there is no suggestion in the literature that innovations are particularly aimed towards environmental or health and safety aspects and other regulatory requirements. However there is generally an accepted dichotomy among product on process innovation though as noted in the first chapter even the boundaries here are blurred as also evidenced by the overlap in the respective two factor solution.

Figure 3.12, Scree plot Effects of Innovation CIS 4

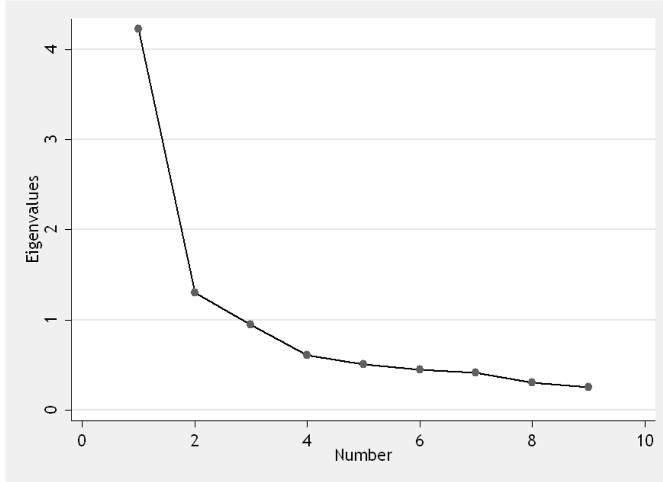


Figure 3.13, Scree plot Effects of Innovation CIS 5

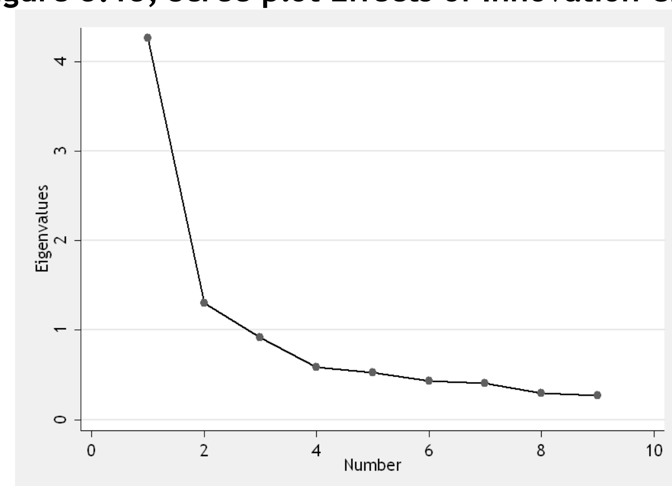


Figure 3.14, Scree plot Effects of Innovation CIS 6

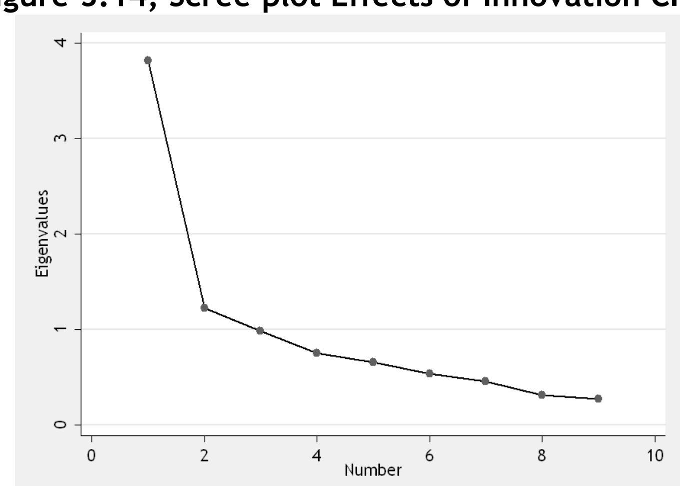


Table 3.19, Factor Analysis Effects of Innovation, CIS 4

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
increased range	-0.10	-0.01	0.90		0.25	0.78
new mkts / mkt share	0.10	-0.09	0.84		0.27	0.79
improved quality	0.33	0.28	0.37		0.45	0.89
flexibility of production	0.89	0.00	0.02		0.20	0.81
capacity of production	0.94	-0.06	-0.02		0.18	0.81
lower cost of production	0.61	0.26	0.06		0.39	0.90
environmental / health & safety	0.16	0.83	-0.09		0.20	0.79
regulatory requirements	-0.10	0.94	0.05		0.18	0.79
increased value added	0.15	0.32	0.53		0.40	0.89
				next factor		
Eigenvalue	4.23	1.30	0.95	0.61		
explained proportion	0.47	0.14	0.11	0.07		
Total (Explained / KMO)	0.36	0.31	0.29			0.83

Table 3.20, Factor Analysis Effects of Innovation, CIS 5

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
increased range	-0.08	-0.01	0.89		0.24	0.76
new mkts / mkt share	0.06	-0.03	0.85		0.26	0.79
improved quality	0.48	0.18	0.31		0.43	0.92
flexibility of production	0.90	-0.05	0.05		0.20	0.83
capacity of production	0.92	-0.03	-0.03		0.20	0.82
lower cost of production	0.57	0.37	-0.08		0.39	0.87
environmental / health & safety	0.08	0.86	-0.02		0.20	0.81
regulatory requirements	-0.08	0.93	0.03		0.19	0.81
increased value added	0.24	0.29	0.47		0.41	0.89
				next factor		
Eigenvalue	4.51	1.17	0.89	0.58		
explained proportion	0.50	0.13	0.10	0.06		
Total (Explained / KMO)	0.37	0.33	0.28			0.83

Table 3.21, Factor Analysis Effects of Innovation, CIS 6

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
increased range	0.04	-0.10	0.83		0.32	0.81
new mkts / mkt share	-0.05	0.14	0.78		0.36	0.84
improved quality	0.44	0.14	0.28		0.55	0.85
flexibility of production	0.87	-0.04	0.05		0.24	0.79
capacity of production	0.89	-0.02	-0.05		0.24	0.79
lower cost of production	0.55	0.38	-0.09		0.44	0.89
environmental / health & safety	0.09	0.88	-0.02		0.17	0.74
regulatory requirements	-0.08	0.92	0.05		0.19	0.73
increased value added	0.46	0.07	0.40		0.47	0.87
				next factor		
Eigenvalue	3.82	1.22	0.98	0.75		
explained proportion	0.42	0.14	0.11	0.08		
Total (Explained / KMO)	0.34	0.28	0.24			0.81

Innovative Activities

Table 3.22, Correlation Matrix Innovative Activities, CIS4

	Intramural R&D	Extramural R&D	Machinery, equipment & software	External knowledge	Training	All forms of Design	Market introduction
Intramural R&D							
Extramural R&D	0.58						
Machinery, equipment & software	0.31	0.34					
External knowledge	0.26	0.45	0.43				
Training	0.33	0.23	0.54	0.45			
All forms of Design	0.54	0.45	0.36	0.40	0.36		
Market introduction	0.40	0.41	0.26	0.37	0.42	0.50	

Table 3.23, Correlation Matrix Innovative Activities, CIS5

	Intramural R&D	Extramural R&D	Machinery, equipment & software	External knowledge	Training	All forms of Design	Market introduction
Intramural R&D							
Extramural R&D	0.61						
Machinery, equipment & software	0.34	0.35					
External knowledge	0.36	0.63	0.39				
Training	0.40	0.40	0.54	0.50			
All forms of Design	0.62	0.47	0.40	0.44	0.50		
Market introduction	0.59	0.41	0.39	0.43	0.51	0.62	

Table 3.24, Correlation Matrix Innovative Activities, CIS6

	Intramural R&D	Extramural R&D	Machinery, equipment & software	External knowledge	Training	All forms of Design	Market introduction
Intramural R&D							
Extramural R&D	0.62						
Machinery, equipment & software	0.46	0.36					
External knowledge	0.42	0.63	0.46				
Training	0.53	0.45	0.59	0.50			
All forms of Design	0.62	0.46	0.37	0.43	0.43		
Market introduction	0.61	0.44	0.46	0.41	0.44	0.66	

Looking at the correlations among ‘innovative activities’ (tables 3.22 – 3.24) the highest correlation is found among ‘extra’ and ‘intramural R&D’ as well as ‘intramural R&D’ and ‘spending on all forms of design’ as well as the later and ‘market introductions’. Also ‘training’ and ‘spending on machinery, equipment and software’ have high correlation among another. In the CIS 5 and the CIS 6 the correlation among ‘intramural R&D’ and ‘market introductions’ and the correlation among ‘external knowledge’ and ‘intramural R&D’ is relatively high. Similar to the aims of innovation question the correlation differences among the CIS 4 and the CIS 5 and the CIS 6 are likely to be to some extent a result of the splitting up of the ‘market introductions’ question and the question about spending on ‘machinery, equipment and software’ into 4 and 3 separate questions respectively[140] which has considerably raised the percentage of firms reporting such activities as has been shown in the data chapter (table 2.21 - 2.23). For instance the correlations among use of ‘advanced machinery’ and ‘computer hardware’ or ‘software’ are between 0.25 and 0.31 for the CIS 5 and the CIS 6. Similarly the correlation among the different components of ‘market introduction of innovations’ do not have perfect correlation among themselves between 0.38 and 0.66 for the CIS 5 and the CIS 6. These results justify the split and imply an increased amount of variability being introduced. However it is difficult to explain why the correlation between external knowledge and intramural R&D is higher for the CIS 5 and the CIS 6. Overall the CIS 5 and the CIS 6 correlations are a lot more similar compared to those observed in the CIS 4.

[140] The question whether firms engaged in ‘market introduction of innovations’ was split to ask respondents whether the engaged in ‘changes to product or service design’, ‘market research’, ‘changes to marketing methods’ and ‘launch advertising’, while the question about engaging in the ‘acquisition of machinery, equipment and software for innovation’ was split asking respondents whether they engaged in acquisition of ‘advanced machinery’, ‘computer hardware’ and ‘computer software’.

Table 3.25, Factor Analysis Innovative Activities, CIS 4

	Factor 1		Uniqueness	KMO
Intramural R&D	0.70		0.51	0.74
Extramural R&D	0.71		0.50	0.73
Machinery, equipment & software	0.66		0.57	0.79
External knowledge	0.69		0.53	0.80
Training	0.68		0.54	0.73
All forms of Design	0.74		0.45	0.83
Market introduction	0.69		0.52	0.82
		next factor		
Eigenvalues (1st, 2nd, ...)	3.39	1.02		
Explained variability				
before rotation	0.48	0.15		
after rotation	0.48		Total KMO	0.78

Table 3.26, Factor Analysis Innovative Activities, CIS 5

	Factor 1		Uniqueness	KMO
Intramural R&D	0.77		0.41	0.81
Extramural R&D	0.72		0.48	0.75
Machinery, equipment & software	0.68		0.54	0.89
External knowledge	0.72		0.48	0.76
Training	0.74		0.46	0.86
All forms of Design	0.78		0.39	0.87
Market introduction	0.77		0.40	0.86
		next factor		
Eigenvalues (1st, 2nd, ...)	3.84	0.85		
Explained variability				
before rotation	0.55	0.12		
after rotation	0.55		Total KMO	0.83

Table 3.27, Factor Analysis Innovative Activities, CIS 6

	Factor 1		Uniqueness	KMO
Intramural R&D	0.79		0.37	0.79
Extramural R&D	0.73		0.46	0.75
Machinery, equipment & software	0.69		0.52	0.83
External knowledge	0.71		0.49	0.75
Training	0.74		0.45	0.85
All forms of Design	0.75		0.44	0.85
Market introduction	0.75		0.44	0.84
		next factor		
Eigenvalues (1st, 2nd, ...)	3.83	0.88		
Explained variability				
before rotation	0.55	0.13		
after rotation	0.55		Total KMO	0.81

Figure 3.15, Scree plot Effects of Innovation CIS 4

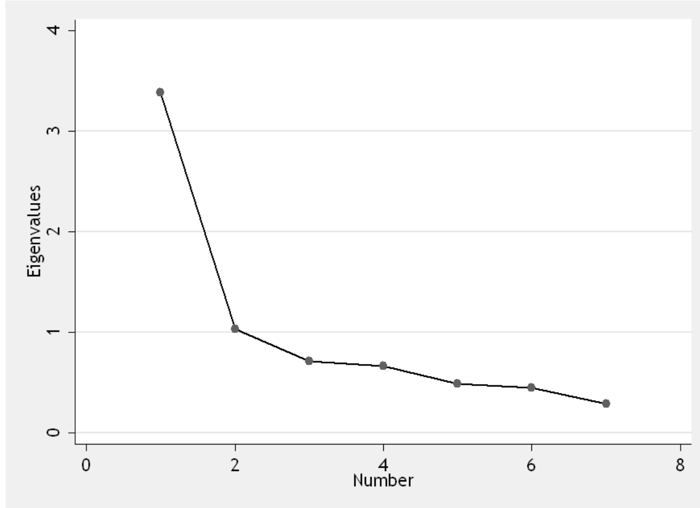


Figure 3.16, Scree plot Effects of Innovation CIS 5

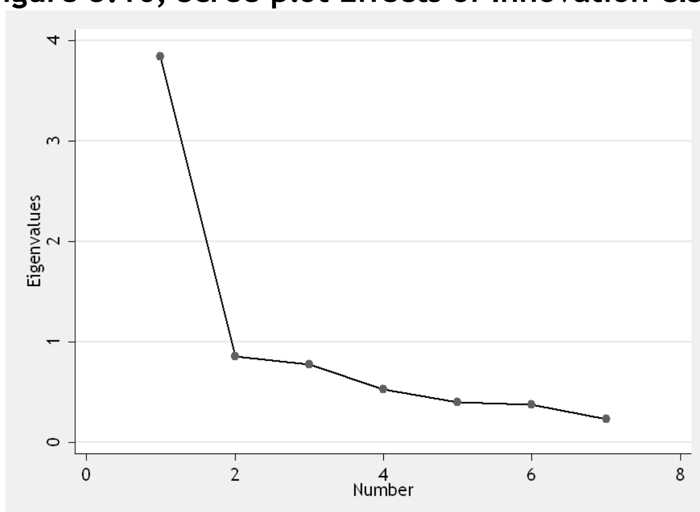
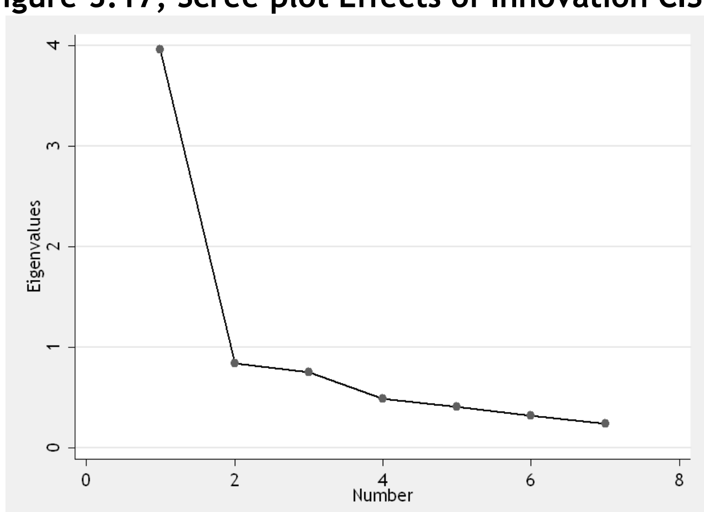


Figure 3.17, Scree plot Effects of Innovation CIS 6



The observed correlations are confirmed in the factor analysis where a single factor is identified according to the Kaiser criterion[141] (tables 3.25 – 3.27). The scree plots (figures 3.15 – 3.17) also confirm a single factor solution[142]. Notably Srholec and Verspagen (2008) identify three factors with eigenvalue larger then unity, a factor centred on R&D activities, another on marketing and training[143] and another on external inputs such as machinery and acquisition of external knowledge. The most likely reason for this difference is that the CIS 3 only asked what sort of innovative activities took place in the last year, rather than the whole survey period as in the CIS 4, this is likely to have caused separate steps of the innovation cycle to be split up and thus being identified separately[144]. Similarly when the analysis is based on firms' innovative activities in the last year as provided by question set on the amount of spending on these activities in the last year of the survey period, which were transformed to dummies depending on whether positive or zero, more factors are identified. While it has often been suggested that firms may decide either to rely on external innovative inputs or on their own resources recent literature has concluded that with increasing complexity of technology this is no longer possible specifically because of the need for absorptive capacity. As a result the various innovative inputs are considered complementary in nature[145] (Granstrand, Patel and Pavitt, 1997, Cassiman and Veuglers, 2006) so identification of a single factor is plausible, while unsatisfactory somewhat in that it only explains slightly over half of the variability in the underlying variables and this is likely to reflect underlying heterogeneity in innovative activities as posited by the evolutionary perspective as well as the different stages in the innovation process at which these inputs are used. Overall this result lends strength to the argument that the OECD manual now

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141 While in the CIS4 two factors arise with an eigenvalue larger than one this is no longer the case for the CIS 5 and CIS 6.

142 Though one may also argue for a two factor solution in the CIS 4 and a three factor solution in the CIS 5 and CIS 6 according to the scree plot.

143 There are no theoretical justifications for these being separate modes. It is likely that what was picked up here are different stage of the innovation cycle, in other words the survey period is too short to cover the whole innovation process from inception to final marketing suggesting that the later is separate from the other stages.

144 Note that for some industries even three years will not be able to cover the whole innovation cycle (Holbrook and Hughes, 2001), indeed being a subject type approach and referring to a specific time frame means that there are likely to be many innovation cycles that are just captured in parts.

145 Most evidence points to the complementarity of sourcing of R&D (Pisano, 1990; Cohen and Malerba, 2001; Cassiman and Veuglers, 2006; Lopez, 2008) as well as innovative activities (Teece, 1986).

considers all these activities as innovative inputs as these "innovation related activities" are clearly used in conjunction with one another by firms.

Information Sources

Table 3.28, Correlation Matrix Sources of Information, CIS4

	Internal	Suppliers	Customers	Competitors	Specialized	HE	Public	Events	Publications	Associations	Standards
Internal											
Suppliers	0.38										
Customers	0.49	0.37									
Competitors	0.34	0.33	0.65								
Specialized	0.28	0.34	0.29	0.34							
HE	0.25	0.21	0.25	0.29	0.55						
Public	0.23	0.25	0.29	0.33	0.57	0.75					
Events	0.27	0.32	0.35	0.43	0.30	0.39	0.42				
Publications	0.26	0.32	0.31	0.36	0.35	0.46	0.48	0.57			
Associations	0.22	0.32	0.34	0.36	0.39	0.44	0.53	0.43	0.66		
Standards	0.32	0.36	0.42	0.38	0.45	0.43	0.49	0.40	0.58	0.69	

Table 3.29, Correlation Matrix Sources of Information, CIS5

	Internal	Suppliers	Customers	Competitors	Specialized	HE	Public	Events	Publications	Associations	Standards
Internal											
Suppliers	0.41										
Customers	0.48	0.37									
Competitors	0.37	0.34	0.64								
Specialized	0.33	0.35	0.32	0.38							
HE	0.29	0.23	0.29	0.32	0.61						
Public	0.27	0.26	0.34	0.40	0.58	0.78					
Events	0.32	0.29	0.36	0.43	0.38	0.47	0.48				
Publications	0.31	0.29	0.32	0.42	0.44	0.53	0.55	0.60			
Associations	0.27	0.33	0.36	0.43	0.44	0.47	0.57	0.50	0.65		
Standards	0.33	0.36	0.43	0.44	0.45	0.43	0.53	0.44	0.57	0.68	

Table 3.30, Correlation Matrix Sources of Information, CIS6

	Internal	Suppliers	Customers	Competitors	Specialized	HE	Public	Events	Publications	Associations	Standards
Internal											
Suppliers	0.33										
Customers	0.36	0.32									
Competitors	0.25	0.30	0.56								
Specialized	0.21	0.33	0.18	0.33							
HE	0.25	0.21	0.17	0.29	0.57						
Public	0.20	0.21	0.22	0.32	0.57	0.77					
Events	0.21	0.32	0.28	0.36	0.40	0.48	0.50				
Publications	0.18	0.29	0.20	0.32	0.48	0.59	0.62	0.57			
Associations	0.20	0.29	0.26	0.38	0.43	0.42	0.54	0.59	0.60		
Standards	0.24	0.34	0.33	0.35	0.43	0.43	0.52	0.46	0.61	0.65	

The importance of the ‘sources of information used for innovations’ show the relatively speaking highest correlation (tables 3.28 – 3.30) among information from ‘customers’ and ‘competitors’ (though this is not true for CIS 6) as well as ‘public’ and ‘HE institutes’ as well as ‘events’ and ‘publications’ and the later with ‘associations’ which in turn show a high correlation with ‘standards’. These correlations are very much in line with the two factor solutions that are identified (tables 3.31 – 3.33) both according to the Kaiser criterion and the scree plots (figures 3.18 – 3.20). That is one factor which is centred on information from generic sources with easily understandable knowledge such as from ‘within the firm’, ‘suppliers’, ‘customers’ and ‘competitors’. The other factor is about more “scientific” knowledge from ‘specialized sources’, ‘Higher Education institutes’, ‘publications’, ‘associations’, etc. These could be related to the different sort of information channels that exist for tacit and codified information. Srholec and Verspagen (2008) again identify one more factor, namely that the use of information from ‘clients’ and ‘industry’ are distinct from use of information from ‘suppliers’ and ‘events’. The identified factors closely correspond to the conceptions identified by Jensen et al. (2007) where the ‘doing and using’ mode stems from the experience and thus tacit information shared among market participants whereas the ‘science and technology’ mode is the one that relies on codified scientific and technological knowledge from specialized resources. This part here in terms of what information has been analysed is close in spirit to the contribution by Pavitt (1984) however unlike his work only two types of information uses emerge, nevertheless if conducted on a confirmatory level 4 (to 6) factors very similar to Pavitt’s classification can be identified.

Table 3.31, Factor Analysis Sources of Information, CIS 4

		Factor 1	Factor 2		Uniqueness	KMO
Internal		-0.06	0.74		0.48	0.85
Suppliers		0.09	0.61		0.57	0.91
Customers		-0.03	0.86		0.29	0.80
Competitors		0.11	0.71		0.41	0.83
Specialized		0.66	0.08		0.52	0.91
HE		0.87	-0.13		0.33	0.82
Public		0.89	-0.11		0.27	0.83
Events		0.47	0.31		0.55	0.90
Publications		0.68	0.14		0.43	0.87
Associations		0.72	0.12		0.39	0.86
Standards		0.61	0.26		0.41	0.89
				next factor		
Eigenvalues (1st, 2nd, ...)		4.96	1.37	0.97		
Explained variability	*before rotation*	0.45	0.12	0.09		
	after rotation	0.40	0.31		Total KMO	0.86

Table 3.32, Factor Analysis Sources of Information, CIS 5

		Factor 1	Factor 2		Uniqueness	KMO
Internal		-0.02	0.76		0.43	0.88
Suppliers		0.02	0.68		0.53	0.91
Customers		-0.04	0.85		0.30	0.82
Competitors		0.10	0.73		0.39	0.86
Specialized		0.61	0.17		0.51	0.92
HE		0.90	-0.13		0.29	0.81
Public		0.91	-0.10		0.24	0.84
Events		0.45	0.34		0.55	0.92
Publications		0.73	0.09		0.40	0.90
Associations		0.72	0.15		0.36	0.89
Standards		0.58	0.29		0.42	0.90
				next factor		
Eigenvalues (1st, 2nd, ...)		5.17	1.40	0.85		
Explained variability	*before rotation*	0.47	0.13	0.08		
	after rotation	0.41	0.34		Total KMO	0.88

Table 3.33, Factor Analysis Sources of Information, CIS 6

		Factor 1	Factor 2		Uniqueness	KMO
Internal		-0.01	0.64		0.60	0.85
Suppliers		0.12	0.61		0.56	0.89
Customers		-0.08	0.86		0.31	0.75
Competitors		0.14	0.70		0.42	0.83
Specialized		0.70	0.06		0.48	0.93
HE		0.86	-0.12		0.33	0.82
Public		0.89	-0.09		0.26	0.85
Events		0.64	0.18		0.47	0.91
Publications		0.84	-0.02		0.31	0.92
Associations		0.69	0.17		0.40	0.87
Standards		0.62	0.25		0.43	0.89
				next factor		
Eigenvalues (1st, 2nd, ...)		4.95	1.48	0.88		
Explained variability	*before rotation*	0.45	0.13	0.08		
	after rotation	0.42	0.27		Total KMO	0.86

Figure 3.18, Scree plot Sources of Information rating CIS 4

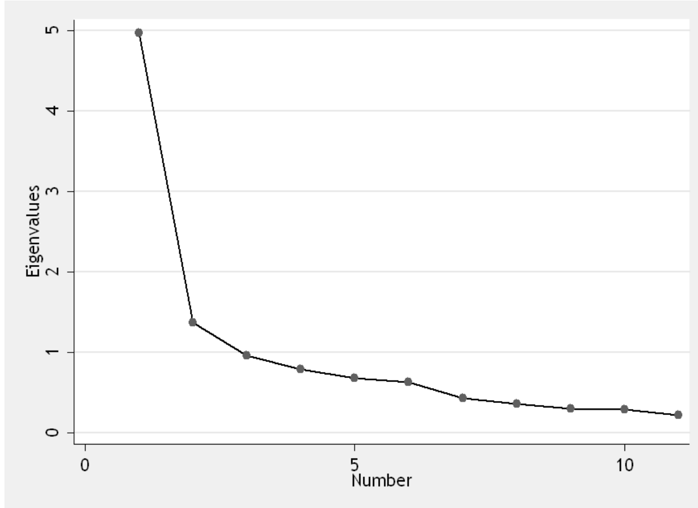


Figure 3.19, Scree plot Sources of Information rating CIS 4

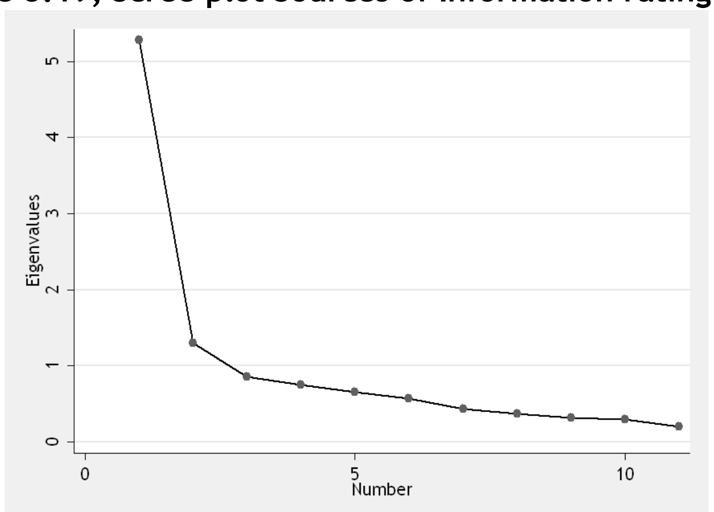
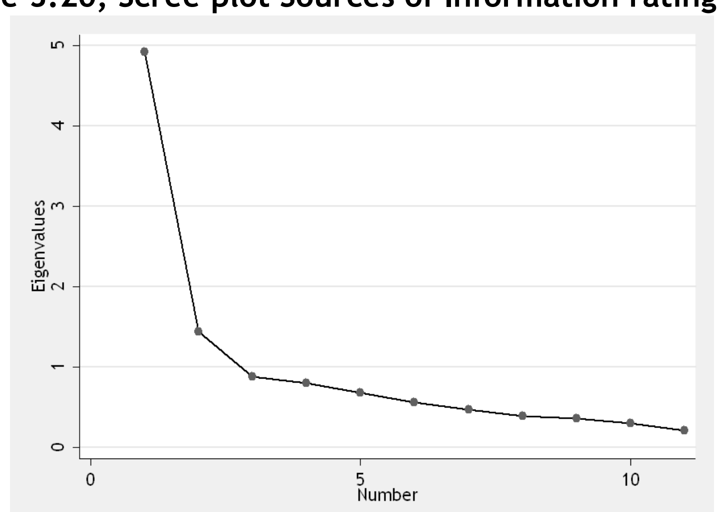


Figure 3.20, Scree plot Sources of Information rating CIS 4



Protection Methods for Innovation

Table 3.34, Correlation Matrix Protection Methods, CIS4

	Design	Trademarks	Patents	Confidentiality	Copyright	Secrecy	Complexity	Leadtime
Design								
Trademarks	0.84							
Patents	0.86	0.82						
Confidentiality	0.63	0.63	0.67					
Copyright	0.75	0.76	0.71	0.69				
Secrecy	0.60	0.59	0.62	0.78	0.66			
Complexity	0.62	0.55	0.63	0.65	0.61	0.76		
Leadtime	0.52	0.49	0.54	0.63	0.54	0.71	0.77	

Table 3.35, Correlation Matrix Protection Methods, CIS5

	Design	Trademarks	Patents	Confidentiality	Copyright	Secrecy	Complexity	Leadtime
Design								
Trademarks	0.83							
Patents	0.86	0.82						
Confidentiality	0.61	0.60	0.64					
Copyright	0.79	0.79	0.79	0.69				
Secrecy	0.60	0.57	0.62	0.81	0.62			
Complexity	0.67	0.58	0.66	0.64	0.63	0.71		
Leadtime	0.56	0.52	0.54	0.60	0.54	0.65	0.71	

The rating of the 'importance of the methods of protection' show the highest correlation among 'design', 'trademarks' and 'patents'. Besides that 'secrecy' and 'confidentiality', 'copyright' as well as 'leadtime', 'complexity' and 'secrecy' also exhibit fairly high correlations among another (table 3.34 and table 3.35). No apparent differences among the surveys exist. Factor analysis identifies one factor with eigenvalue larger then 1 (table 3.36 and table 3.37), though the scree plots (figure 3.21 and 3.22) may also suggest a two or a three factor solution. A two factor solution gives rise to one being centred on 'formal' protection methods and a second one on 'informal' protection methods with 'confidentiality agreements' cross-loading across both factors. A two factor solution with 'informal' and 'formal' protection methods has also been identified in the work of Srholec and Verspagen (2008). There is reason to believe that formal and informal protection methods may be distinct as formal protection has often been found limited to certain industries (Patel and Pavitt, 1995; Smith, 2005). On the other hand this does not imply that appropriation methods are distinct in their use and their complementarity has also been identified in the literature (Teece, 1986; Dosi, Marengo and Pasquali, 2006) and thus retaining a single factor that explains around three quarter of the underlying variability in the responses to this question set is deemed reasonable.

Table 3.36, Factor Analysis Protection Methods, CIS 4

		Factor 1		Uniqueness	KMO
Design		0.87		0.24	0.89
Trademarks		0.85		0.28	0.91
Patents		0.88		0.23	0.90
Confidentiality		0.84		0.29	0.92
Copyright		0.85		0.27	0.95
Secrecy		0.85		0.28	0.90
Complexity		0.83		0.32	0.89
Leadtime		0.77		0.41	0.91
			next factor		
Eigenvalues (1st, 2nd, …)		5.68	0.90		
Explained variability					
	before rotation	0.71	0.11		
	after rotation	0.71		Total KMO	0.91

Table 3.37, Factor Analysis Protection Methods, CIS 5

		Factor 1		Uniqueness	KMO
Design		0.88		0.22	0.91
Trademarks		0.86		0.26	0.91
Patents		0.87		0.24	0.92
Confidentiality		0.85		0.28	0.88
Copyright		0.87		0.24	0.94
Secrecy		0.83		0.32	0.88
Complexity		0.83		0.31	0.92
Leadtime		0.78		0.39	0.92
			next factor		
Eigenvalues (1st, 2nd, …)		5.75	0.84		
Explained variability					
	before rotation	0.72	0.11		
	after rotation	0.72		Total KMO	0.91

Figure 3.21, Scree plot Sources of Information rating CIS 4

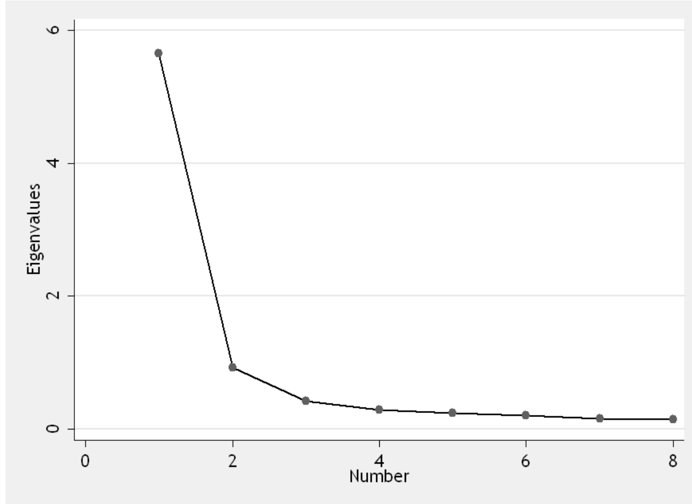
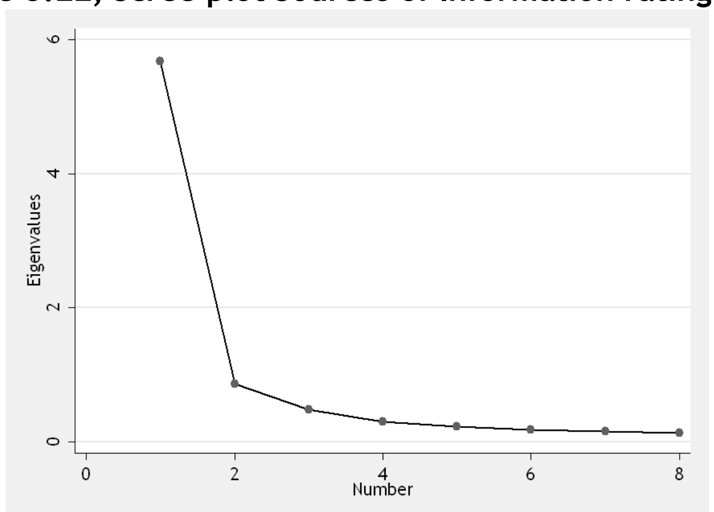


Figure 3.22, Scree plot Sources of Information rating CIS 4



Cooperation Partners

Table 3.38, Correlation Matrix Cooperation Partners, CIS4

	Other enterprises within the enterprise group	Suppliers of equipment, materials, services, or software	Clients or customers	Competitors or other enterprises in the industry	Consultant, commercial labs, or private R&D institutes	Universities or other higher education institutions	Government or public research institutes
Other enterprises within the enterprise group							
Suppliers of equipment, materials, services, or software	0.85						
Clients or customers	0.86	0.93					
Competitors or other enterprises in the industry	0.81	0.83	0.88				
Consultant, commercial labs, or private R&D institutes	0.78	0.88	0.85	0.80			
Universities or other HE institutions	0.73	0.77	0.80	0.74	0.80		
Government or public research institutes	0.73	0.77	0.81	0.81	0.83	0.86	

Table 3.39, Correlation Matrix Cooperation Partners, CIS5

	Other enterprises within the enterprise group	Suppliers of equipment, materials, services, or software	Clients or customers	Competitors or other enterprises in the industry	Consultant, commercial labs, or private R&D institutes	Universities or other higher education institutions	Government or public research institutes
Other enterprises within the enterprise group							
Suppliers of equipment, materials, services, or software	0.87						
Clients or customers	0.85	0.90					
Competitors or other enterprises in the industry	0.81	0.82	0.83				
Consultant, commercial labs, or private R&D institutes	0.79	0.84	0.82	0.78			
Universities or other higher education institutions	0.75	0.72	0.77	0.74	0.81		
Government or public research institutes	0.77	0.74	0.79	0.78	0.84	0.86	

Table 3.40, Correlation Matrix Cooperation Partners, CIS6

	Other enterprises within the enterprise group	Suppliers of equipment, materials, services, or software	Clients or customers	Competitors or other enterprises in the industry	Consultant, commercial labs, or private R&D institutes	Universities or other higher education institutions	Government or public research institutes
Other enterprises within the enterprise group							
Suppliers of equipment, materials, services, or software	0.67						
Clients or customers	0.68	0.68					
Competitors or other enterprises in the industry	0.72	0.62	0.72				
Consultant, commercial labs, or private R&D institutes	0.63	0.67	0.60	0.72			
Universities or other higher education institutions	0.67	0.62	0.68	0.71	0.81		
Government or public research institutes	0.70	0.63	0.69	0.80	0.80	0.89	

Correlations among 'cooperation partners used' are fairly high (tables 3.38 – 3.40)[146], however in the CIS 6 these correlations are somewhat lower except for the ones among 'government or public research institutes', 'Universities or HE institutions' and 'consultant, commercial or private R&D institutes'. This observation is accompanied by the much larger percentage of positive responses to this question set in the CIS 6 which is at 60% instead of 24% and 20% for the CIS 4 and the CIS 5 respectively. A single factor is identified according to the Kaiser criterion for cooperation partner used (tables 3.41 – 3.43) and according to the scree plots (figures 3.23 – 3.25) which explains 84%, 82% and 74% of the variability of the cooperation partners used for the CIS4, the CIS 5 and the CIS 6 respectively. Use of this sort of lower order factor also seems more suitable then as Srholec and

[146] This was obtained by transforming the content so as to ignore the regional information where the cooperation partner stems from, like for innovative inputs it was only relevant that the firm reported to have had a certain partner. As noted by Kolenikov and Angeles (2004) using all the geographic information together in a factor analysis would lead to spurious correlations as they measure one and the same aspect along different geographic dimensions.

Verspagen (2008) have done to use a dummy indicator representing the use of cooperation partners for the higher-order factor analysis[147], since it provides for a continuous variable as is available from the other lower order factors, which strictly speaking is required for carrying out valid factor analysis.

[147] Which they themselves argue should be based on continuous variables or assumed continuous latent variables as when using polychoric correlation matrixes.

Table 3.41, Factor Analysis Cooperation Partners, CIS 4

	Factor 1		Uniqueness	KMO
Other enterprises within the enterprise group	0.90		0.19	0.97
Suppliers of equipment, materials, services, or software	0.94		0.11	0.88
Clients or customers	0.95		0.09	0.89
Competitors or other enterprises in the industry	0.91		0.17	0.93
Consultant, commercial labs, or private R&D institutes	0.93		0.14	0.93
Universities or other higher education institutions	0.88		0.22	0.91
Government or public research institutes	0.91		0.18	0.89
		next factor		
Eigenvalue	5.89	0.39	0.39	
explained proportion	0.84	0.06		
Total (Explained / KMO)	0.84		Total KMO	0.91

Table 3.42, Factor Analysis Cooperation Partners, CIS 5

	Factor 1		Uniqueness	KMO
Other enterprises within the enterprise group	0.91		0.17	0.93
Suppliers of equipment, materials, services, or software	0.91		0.18	0.81
Clients or customers	0.93		0.13	0.90
Competitors or other enterprises in the industry	0.91		0.17	0.95
Consultant, commercial labs, or private R&D institutes	0.91		0.16	0.91
Universities or other higher education institutions	0.87		0.24	0.90
Government or public research institutes	0.91		0.18	0.80
		next factor		
Eigenvalue	5.77	0.46		
explained proportion	0.82	0.07		
Total (Explained / KMO)	0.82		Total KMO	0.89

Table 3.43, Factor Analysis Cooperation Partners, CIS 6

	Factor 1		Uniqueness	KMO
Other enterprises within the enterprise group	0.83		0.32	0.95
Suppliers of equipment, materials, services, or software	0.80		0.36	0.90
Clients or customers	0.83		0.31	0.90
Competitors or other enterprises in the industry	0.88		0.23	0.88
Consultant, commercial labs, or private R&D institutes	0.87		0.24	0.91
Universities or other higher education institutions	0.90		0.20	0.84
Government or public research institutes	0.93		0.14	0.85
		next factor		
Eigenvalue	5.21	0.55		
explained proportion	0.74	0.08		
Total (Explained / KMO)	0.74		Total KMO	0.89

Figure 3.23, Scree plot Cooperation Partners used CIS 4

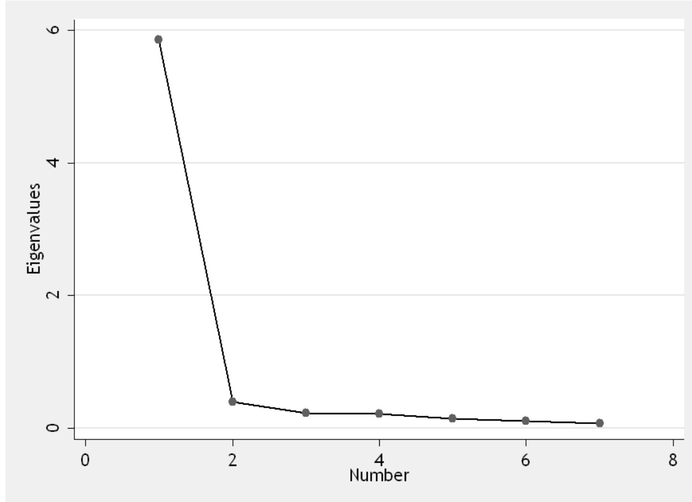


Figure 3.24, Scree plot Cooperation Partners used CIS 5

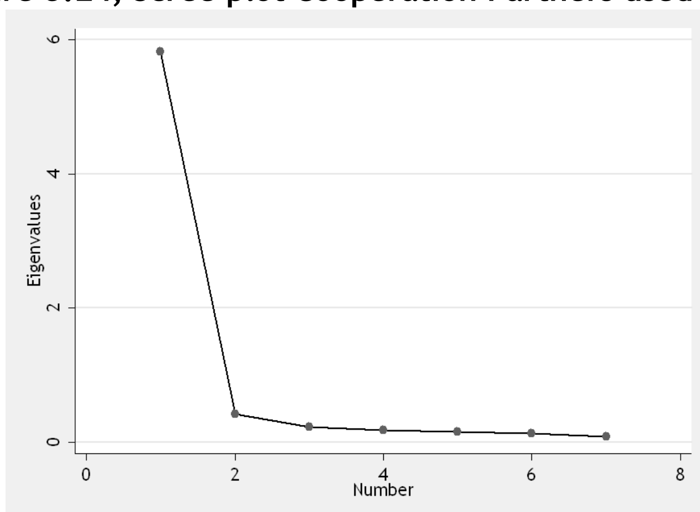
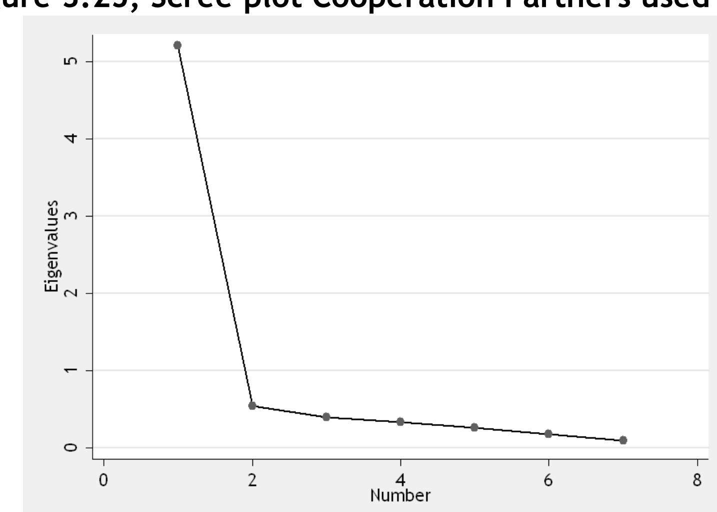


Figure 3.25, Scree plot Cooperation Partners used CIS 6



Barriers to Innovation

Table 3.44, Correlation Matrix Barriers to Innovation, CIS4

	Economic risk	Innovation cost	Finance cost	Finance availability	Lack of personnel	Lack of technology info	Lack of market info	Incumbents market power	Uncertain demand	Meet UK regulations	Meet EU regulations
Economic risk											
Innovation cost	0.74										
Finance cost	0.58	0.65									
Finance availability	0.49	0.53	0.81								
Lack of personnel	0.40	0.46	0.41	0.39							
Lack of technology info	0.46	0.51	0.44	0.42	0.72						
Lack of market info	0.46	0.47	0.41	0.41	0.61	0.73					
Incumbents market power	0.46	0.46	0.41	0.39	0.44	0.49	0.57				
Uncertain demand	0.52	0.50	0.39	0.38	0.42	0.47	0.57	0.66			
Meet UK regulations	0.35	0.34	0.38	0.36	0.37	0.42	0.41	0.43	0.38		
Meet EU regulations	0.37	0.36	0.39	0.35	0.36	0.43	0.43	0.44	0.40	0.91	

Table 3.45, Correlation Matrix Barriers to Innovation, CIS5

	Economic risk	Innovation cost	Finance cost	Finance availability	Lack of personnel	Lack of technology info	Lack of market info	Incumbents market power	Uncertain demand	Meet UK regulations	Meet EU regulations
Economic risk											
Innovation cost	0.80										
Finance cost	0.62	0.71									
Finance availability	0.57	0.62	0.85								
Lack of personnel	0.50	0.55	0.54	0.53							
Lack of technology info	0.55	0.59	0.58	0.58	0.74						
Lack of market info	0.58	0.58	0.55	0.55	0.66	0.78					
Incumbents market power	0.56	0.57	0.52	0.51	0.55	0.60	0.67				
Uncertain demand	0.60	0.60	0.49	0.50	0.53	0.59	0.67	0.71			
Meet UK regulations	0.48	0.47	0.50	0.48	0.47	0.52	0.49	0.50	0.47		
Meet EU regulations	0.51	0.50	0.51	0.50	0.48	0.54	0.52	0.50	0.48	0.92	

Table 3.46, Correlation Matrix Barriers to Innovation, CIS6

	Economic risk	Innovation cost	Finance cost	Finance availability	Lack of personnel	Lack of technology info	Lack of market info	Incumbents market power	Uncertain demand	Meet UK regulations	Meet EU regulations
Economic risk											
Innovation cost	0.74										
Finance cost	0.59	0.68									
Finance availability	0.53	0.58	0.85								
Lack of personnel	0.39	0.50	0.45	0.45							
Lack of technology info	0.43	0.54	0.49	0.47	0.75						
Lack of market info	0.44	0.50	0.42	0.42	0.66	0.77					
Incumbents market power	0.41	0.48	0.37	0.36	0.51	0.55	0.62				
Uncertain demand	0.47	0.49	0.32	0.31	0.46	0.52	0.61	0.62			
Meet UK regulations	0.45	0.45	0.43	0.42	0.43	0.51	0.47	0.49	0.46		
Meet EU regulations	0.46	0.46	0.44	0.40	0.43	0.51	0.47	0.49	0.45	0.90	

The 'barriers to innovation' question has been quite considerably rephrased, specifically with respect to who these questions are targeted at. While in the CIS 4 it is about constraints to innovative activities but also about causes for not innovating in the CIS 5 it is only concerning the reason why firms did not innovate and in the CIS 6 it is simply about constraints experienced during innovative activities that have been undertaken. Despite these changes the correlations (tables 3.44 – 3.46) while being substantially higher for the CIS 5, were in general very similar across the surveys. With the highest correlations among 'innovation cost' and 'economic risk', 'finance cost' and 'finance availability', 'lack of personnel' and 'lack of technology information' as well as 'meeting EU regulations' and 'meeting UK regulations'. Also the identified factors (table 3.47 – 3.49) were very similar even for the CIS 5 when ignoring the Kaiser criterion which suggests a three factor solution for the CIS 4 and the CIS 6 and a one factor solution for the CIS 5, while the Scree plots (figures 3.26 – 3.28) suggest a one or 5 factor solution. Since only firms with innovative activates have been asked this question it would be expected that the variability for reasons for not innovating (the population this question is targeted at in the CIS 5) would indeed be substantially reduced and thus less factors emerge. It also suggests that the way the barriers are perceived in terms of their relation to one another is not so different for innovators and non-innovators. While there is no theoretical literature on the barriers of innovation, the empirical work by Piatier (1984) in this area finds three main barriers related to 'skill', 'finance' and 'regulation' which very much correspond to what is found here. These lower order factors are not included in the higher order factors analysis similar to Srholec and Verspagen (2008) who do not carry out a factor analysis on this question set in the first place.

Table 3.47, Factor Analysis Barriers to Innovation, CIS 4

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
Economic risk	0.24	0.68	-0.05		0.35	0.89
Innovation cost	0.25	0.73	-0.09		0.27	0.88
Finance cost	-0.09	0.94	0.06		0.16	0.81
Finance availability	-0.08	0.88	0.06		0.26	0.82
Lack of personnel	0.84	-0.01	-0.05		0.34	0.90
Lack of technology info	0.85	0.01	0.02		0.25	0.87
Lack of market info	0.87	-0.03	0.04		0.24	0.91
Incumbents market power	0.60	0.08	0.19		0.43	0.92
Uncertain demand	0.62	0.15	0.07		0.44	0.90
Meet UK regulations	0.01	0.00	0.97		0.05	0.73
Meet EU regulations	0.03	0.01	0.95		0.05	0.74
				next factor		
Eigenvalues (1st, 2nd, …)	5.77	1.27	1.12	0.82		
Explained variability *before rotation*	0.52	0.12	0.10	0.07		
after rotation	0.43	0.39	0.30		Total KMO	0.85

Table 3.48, Factor Analysis Barriers to Innovation, CIS 5

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
Economic risk	0.20	0.70	-0.02		0.29	0.91
Innovation cost	0.21	0.78	-0.08		0.21	0.90
Finance cost	-0.11	0.95	0.08		0.14	0.86
Finance availability	-0.03	0.89	0.04		0.21	0.87
Lack of personnel	0.81	-0.01	0.02		0.33	0.95
Lack of technology info	0.85	-0.02	0.08		0.23	0.91
Lack of market info	0.91	-0.04	0.03		0.19	0.92
Incumbents market power	0.74	0.07	0.04		0.34	0.94
Uncertain demand	0.77	0.13	-0.06		0.30	0.93
Meet UK regulations	0.01	0.00	0.96		0.05	0.81
Meet EU regulations	0.03	0.02	0.95		0.05	0.82
				next factor		
Eigenvalues (1st, 2nd, …)	6.89	0.95	0.83	0.62		
Explained variability *before rotation*	0.63	0.09	0.08	0.06		
after rotation	0.55	0.51	0.39		Total KMO	0.89

Table 3.49, Factor Analysis Barriers to Innovation, CIS 4

	Factor 1	Factor 2	Factor 3		Uniqueness	KMO
Economic risk	0.07	0.66	0.16		0.37	0.90
Innovation cost	0.22	0.70	0.03		0.27	0.90
Finance cost	-0.05	0.95	0.01		0.13	0.81
Finance availability	-0.03	0.92	-0.02		0.20	0.82
Lack of personnel	0.84	0.10	-0.12		0.30	0.92
Lack of technology info	0.84	0.09	-0.03		0.23	0.88
Lack of market info	0.91	-0.03	-0.01		0.21	0.90
Incumbents market power	0.71	-0.07	0.20		0.37	0.93
Uncertain demand	0.71	-0.07	0.18		0.39	0.92
Meet UK regulations	0.01	0.03	0.94		0.07	0.79
Meet EU regulations	0.01	0.03	0.95		0.07	0.79
				next factor		
Eigenvalues (1st, 2nd, …)	6.12	1.28	1.01	0.74		
Explained variability *before rotation*	0.56	0.12	0.09	0.07		
after rotation	0.46	0.41	0.35		Total KMO	0.87

Figure 3.26, Scree plot Cooperation Partners used CIS 4

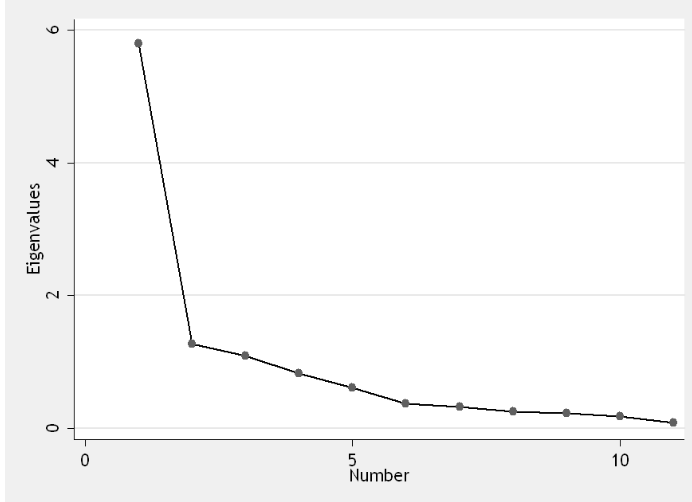


Figure 3.27, Scree plot Cooperation Partners used CIS 5

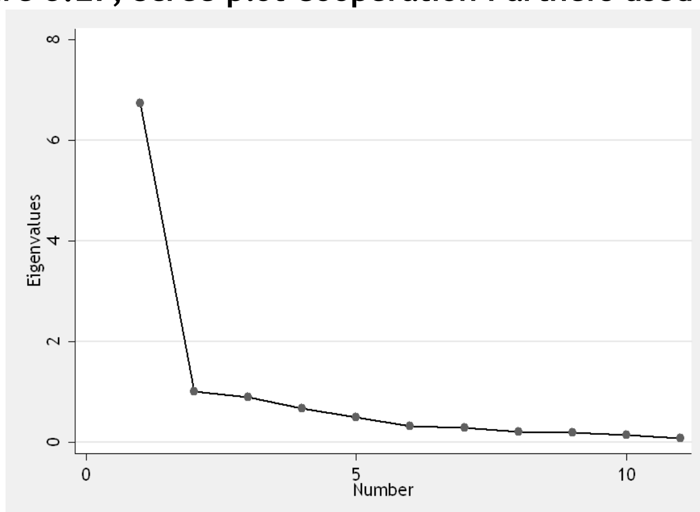
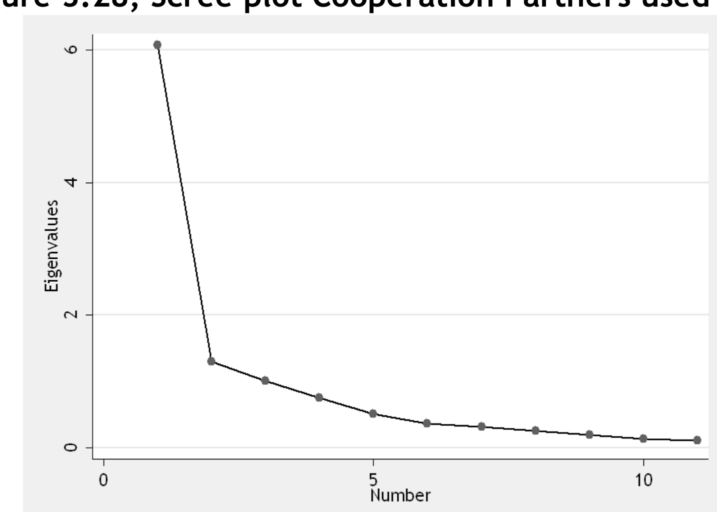


Figure 3.28, Scree plot Cooperation Partners used CIS 6



Wider innovation

Table 3.50, Correlation Matrix Wider Innovation, CIS4

	Corporate strategy	Management techniques	Organizational structure	Marketing concepts or strategies
Corporate strategy				
Management techniques	0.54			
Organizational structure	0.70	0.53		
Marketing concepts or strategies	0.59	0.50	0.55	

Table 3.51, Correlation Matrix Wider Innovation, CIS5

	Corporate strategy	Management techniques	Organizational structure	Marketing concepts or strategies
Corporate strategy				
Management techniques	0.53			
Organizational structure	0.69	0.60		
Marketing concepts or strategies	0.63	0.43	0.62	

Table 3.52, Correlation Matrix Wider Innovation, CIS6

	Corporate strategy	Management techniques	Organizational structure	Marketing concepts or strategies
Corporate strategy				
Management techniques	0.53			
Organizational structure	0.63	0.58		
Marketing concepts or strategies	0.64	0.44	0.56	

The highest correlation for the answers to 'wider forms of innovation' pursued (table 3.50 – 3.52) is found among changes in 'organisational structure' and 'corporate strategy' and the lowest among changes in 'management techniques' and 'marketing'. Variation in the use of wider forms of innovation also just gives rise to a single factor explaining between 67 and 70% of the variations (tables 3.53 – 3.54). Due to the criticism around the ad hoc implementation of this question and its vague phrasing which is related to the infancy of the literature on organisational innovation, not much can be said about the identified factor and it has thus simply been dubbed "wider" innovation. Srholec and Verspagen (2008) have likewise identified a single factor solution.

Table 3.53, Factor Analysis Wider Innovation, CIS 4

	Factor 1		Uniqueness	KMO
Corporate strategy	0.87		0.25	0.76
Management techniques	0.78		0.40	0.86
Organizational structure	0.85		0.27	0.77
Marketing concepts or strategies	0.79		0.37	0.85
		next factor		
Eigenvalues (1st, 2nd, …)	2.71	0.51		
Explained variability				
before rotation	0.68	0.13		
after rotation	0.68		Total KMO	0.80

Table 3.54, Factor Analysis Wider Innovation, CIS 5

	Factor 1		Uniqueness	KMO
Corporate strategy	0.86		0.26	0.80
Management techniques	0.78		0.38	0.85
Organizational structure	0.88		0.23	0.78
Marketing concepts or strategies	0.82		0.33	0.84
		next factor		
Eigenvalues (1st, 2nd, …)	2.79	0.53		
Explained variability				
before rotation	0.70	0.13		
after rotation	0.70		Total KMO	0.81

Table 3.55, Factor Analysis Wider Innovation, CIS 6

	Factor 1		Uniqueness	KMO
Corporate strategy	0.86		0.26	0.77
Management techniques	0.77		0.41	0.83
Organizational structure	0.85		0.28	0.79
Marketing concepts or strategies	0.80		0.36	0.81
		next factor		
Eigenvalues (1st, 2nd, …)	2.69	0.58		
Explained variability				
before rotation	0.67	0.14		
after rotation	0.67		Total KMO	0.80

Public Support

Table 3.56, Correlation Matrix Public support for Innovation, CIS4

	Local or regional	Central or devolved	European Union
Local or regional			
Central or devolved	0.57		
European Union	0.52	0.60	

Table 3.57, Correlation Matrix Public support for Innovation, CIS6

	Local or regional	Central or devolved	European Union
Local or regional			
Central	0.43		
European Union	0.61	0.56	

Questions about the receipt of 'government support' are only available in the CIS 4 and the CIS 6. The correlations (table 3.56 and table 3.57) have changed across the datasets likely in parts because while in the CIS 4 receipt of support from 'central government' and 'devolved administration' were part of a single question in the CIS 6 'devolved administration' was considered part of 'local or regional' support. Giving rise to a single factor (table 3.58 and 3.59) suggests that the aims of these various programs are very similar (or at least the demand and application by firms) and thus the very same firms receive the support from different levels of government, on the other hand use of only 3 variables for factor analysis is not likely to lead to more than one factor emerging as the underlying variability is too small to give rise to more factors. This question set has like the barriers of innovation question been disregarded in the work of Srholec and Verspagen (2008).

Table 3.58, Factor Analysis Public Support for Innovation, CIS 4

	Factor 1		Uniqueness	KMO
Local or regional	0.82		0.33	0.74
Central or devolved	0.86		0.26	0.67
European union	0.84		0.29	0.70
		next factor		
Eigenvalues (1st, 2nd, …)	2.12	0.49		
Explained variability				
before rotation	0.71	0.16		
after rotation	0.71		Total KMO	0.70

Table 3.59, Factor Analysis Public Support for Innovation, CIS 6

	Factor 1		Uniqueness	KMO
Local or regional	0.79		0.37	0.68
Central	0.79		0.38	0.69
European union	0.88		0.22	0.60
		next factor		
Eigenvalues (1st, 2nd, …)	2.03	0.61		
Explained variability				
before rotation	0.68	0.20		
after rotation	0.68		Total KMO	0.66

3.7. Appendix – Higher Order Factor Analysis

Table 3.60, Higher order factor analysis (varimax), CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.65	0.16		0.55	0.8
Product Aim	0.77	-0.11		0.39	0.73
Inputs	0.51	0.4		0.58	0.82
Science Sources	0.47	0.58		0.44	0.73
Market Sources	0.77	0.19		0.37	0.74
Cooperation	-0.02	0.89		0.21	0.73
			next factor		
Eigenvalue	2.44	1	0.79		
explained proportion	0.41	0.17	0.13		
Total (Explained / KMO)	0.35	0.23			0.76

Table 3.61, Higher order factor analysis (varimax), CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.67	0.17		0.52	0.81
Product Aim	0.73	-0.09		0.46	0.76
Inputs	0.44	0.58		0.47	0.79
Science Sources	0.47	0.58		0.44	0.75
Market Sources	0.75	0.17		0.4	0.75
Cooperation	-0.06	0.86		0.25	0.72
			next factor		
Eigenvalue	2.42	1.03	0.75		
explained proportion	0.4	0.17	0.12		
Total (Explained / KMO)	0.33	0.25			0.76

Table 3.62, Higher order factor analysis (varimax), CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.81	-0.03		0.34	0.77
Product Aim	0.64	0.17		0.56	0.72
Inputs	0.34	0.51		0.62	0.79
Science Sources	0.42	0.62		0.44	0.74
Market Sources	0.71	0.23		0.45	0.76
Cooperation	-0.04	0.87		0.24	0.73
			next factor		
Eigenvalue	2.36	1.01	0.81		
explained proportion	0.39	0.17	0.13		
Total (Explained / KMO)	0.31	0.25			0.75

Table 3.63, Higher order factor analysis (oblimin, gamma 0.5), CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.66	0.06		0.55	0.8
Product Aim	0.8	-0.23		0.39	0.73
Inputs	0.49	0.32		0.58	0.82
Science Sources	0.43	0.52		0.44	0.73
Market Sources	0.77	0.07		0.37	0.74
Cooperation	-0.09	0.9		0.21	0.73
			next factor		
Eigenvalue	2.44	1	0.79		
explained proportion	0.41	0.17	0.13		
Total (Explained / KMO)	0.38	0.24			0.76

Table 3.64, Higher order factor analysis (oblimin, gamma 0.5), CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.68	0.06		0.52	0.81
Product Aim	0.76	-0.21		0.46	0.76
Inputs	0.39	0.52		0.47	0.79
Science Sources	0.43	0.51		0.44	0.75
Market Sources	0.76	0.04		0.4	0.75
Cooperation	-0.15	0.89		0.25	0.72
			next factor		
Eigenvalue	2.42	1.03	0.75		
explained proportion	0.4	0.17	0.12		
Total (Explained / KMO)	0.36	0.27			0.76

Table 3.65, Higher order factor analysis (oblimin, gamma 0.5), CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.83	-0.15		0.34	0.77
Product Aim	0.64	0.08		0.56	0.72
Inputs	0.3	0.47		0.62	0.79
Science Sources	0.37	0.57		0.44	0.74
Market Sources	0.7	0.13		0.45	0.76
Cooperation	-0.11	0.89		0.24	0.73
			next factor		
Eigenvalue	2.36	1.01	0.81		
explained proportion	0.39	0.17	0.13		
Total (Explained / KMO)	0.34	0.27			0.75

Table 3.66, Higher order factor analysis (oblimin, gamma 1.0), CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.72	-0.1		0.55	0.8
Product Aim	0.94	-0.44		0.39	0.73
Inputs	0.48	0.24		0.58	0.82
Science Sources	0.37	0.47		0.44	0.73
Market Sources	0.85	-0.11		0.37	0.74
Cooperation	-0.29	1.02		0.21	0.73
			next factor		
Eigenvalue	2.44	1	0.79		
explained proportion	0.41	0.17	0.13		
Total (Explained / KMO)	0.4	0.28			0.76

Table 3.67, Higher order factor analysis (oblimin, gamma 1.0), CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.76	-0.12		0.52	0.81
Product Aim	0.91	-0.44		0.46	0.76
Inputs	0.34	0.47		0.47	0.79
Science Sources	0.38	0.45		0.44	0.75
Market Sources	0.86	-0.15		0.4	0.75
Cooperation	-0.35	1.03		0.25	0.72
			next factor		
Eigenvalue	2.42	1.03	0.75		
explained proportion	0.4	0.17	0.12		
Total (Explained / KMO)	0.76	0.65			0.76

Table 3.68, Higher order factor analysis (oblimin, gamma 1.0), CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.84	-0.16		0.34	0.77
Product Aim	0.64	0.07		0.56	0.72
Inputs	0.29	0.47		0.62	0.79
Science Sources	0.36	0.57		0.44	0.74
Market Sources	0.7	0.13		0.45	0.76
Cooperation	-0.14	0.9		0.24	0.73
			next factor		
Eigenvalue	2.36	1.01	0.81		
explained proportion	0.39	0.17	0.13		
Total (Explained / KMO)	0.34	0.27			0.75

Table 3.69, Higher order factor analysis with "extra aim", CIS 4

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.75	-0.19		0.47	0.79
Product Aim	0.69	-0.06		0.54	0.76
Extra Aim	0.63	-0.01		0.61	0.76
Inputs	0.4	0.43		0.58	0.83
Science Sources	0.44	0.5		0.46	0.76
Market Sources	0.69	0.17		0.44	0.76
Cooperation	-0.09	0.88		0.25	0.75
			next factor		
Eigenvalue	2.63	1.03	0.92		
explained proportion	0.38	0.15	0.13		
Total (Explained / KMO)	0.35	0.21			0.77

Table 3.70, Higher order factor analysis with "extra aim", CIS 5

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.74	-0.13		0.48	0.76
Product Aim	0.64	-0.07		0.6	0.8
Extra Aim	0.67	0.05		0.53	0.76
Inputs	0.3	0.6		0.47	0.8
Science Sources	0.37	0.56		0.44	0.76
Market Sources	0.67	0.14		0.48	0.77
Cooperation	-0.16	0.86		0.31	0.73
			next factor		
Eigenvalue	2.62	1.07	0.87		
explained proportion	0.37	0.15	0.12		
Total (Explained / KMO)	0.33	0.25			0.77

Table 3.71, Higher order factor analysis with "extra aim", CIS 6

	Factor 1	Factor 2		Uniqueness	KMO
Process Aim	0.73	-0.13		0.5	0.76
Product Aim	0.7	-0.11		0.53	0.76
Extra Aim	0.53	0.2		0.62	0.76
Inputs	0.3	0.45		0.65	0.8
Science Sources	0.34	0.6		0.43	0.75
Market Sources	0.67	0.16		0.47	0.78
Cooperation	-0.12	0.87		0.27	0.73
			next factor		
Eigenvalue	2.49	1.04	0.91		
explained proportion	0.36	0.15	0.13		
Total (Explained / KMO)	0.31	0.24			0.76

Figure 3.29, Scree plot Higher Order Factor Analysis with “extra aim” CIS 4

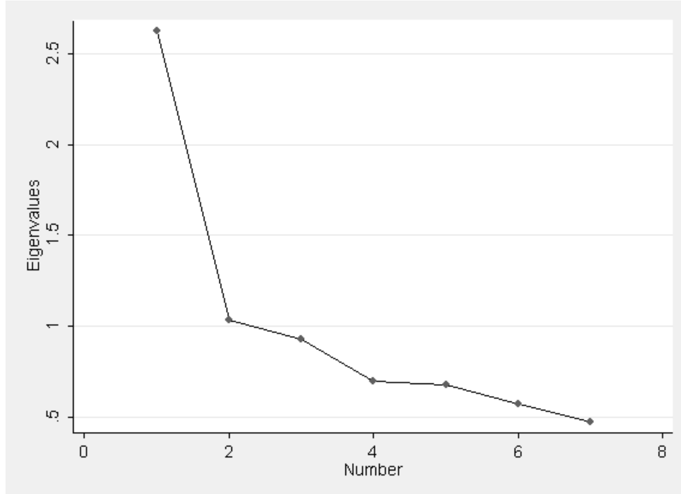


Figure 3.30, Scree plot Higher Order Factor Analysis with “extra aim” CIS 5

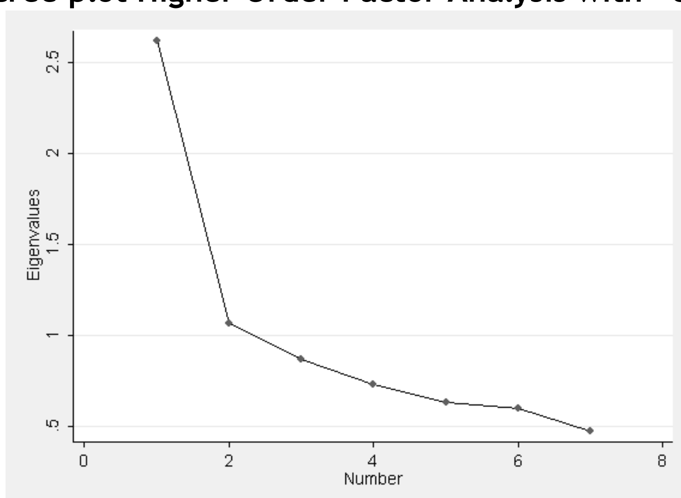
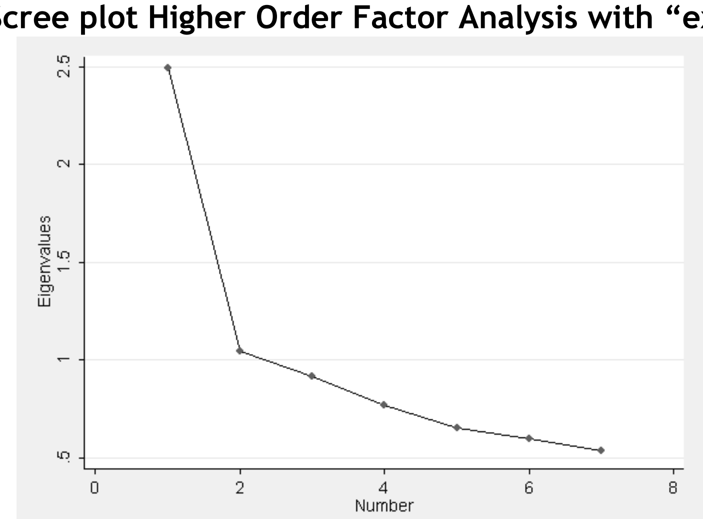


Figure 3.31, Scree plot Higher Order Factor Analysis with “extra aim” CIS 6



3.8. Appendix – Literature Absorptive capacity, Appropriability

Appropriation and absorptive capacity for which measures are to be created are both notions closely related to knowledge spillovers discussed in the introduction chapter, as Cassiman and Veugelers (2002) explain: "firms aim to maximize absorption of spillovers and minimize outgoing spillovers". The appropriation of knowledge allows firms to gain monopolistic returns while absorptive capacity is essential for generating this knowledge in the first place. According to the RBV firms need to rely on their capabilities to maintain a competitive advantage. Hence absorptive capacity and appropriation can be interpreted as key capabilities of a firm. In a similar vein Ireland, Hitt and Simon (2003) contend that the role of strategic entrepreneurship is balancing "opportunity-seeking" and (competitive) "advantage-seeking". The former related to a firm's absorptive capacity and the later to its appropriation methods used. The following section describes these two topics in more detail and shows how their measurement is closely connected with the measurement of knowledge spillovers.

Griliches (1992) points out that the measurement of knowledge spillovers is a rather difficult undertaking (also see Kaiser, 2002a for a discussion of their measurement). In his article he explicates how R&D figures as well as patent citations can be used to measure knowledge spillovers and what sort of problems these approaches involve, mostly these are related to the nature of knowledge which is cumulative, difficult to quantify and thoroughly characterize. In the empirical literature R&D spending and patent citations have been used to investigate the role of spillovers in the inter-industry context (Scherer, 1982, Verspagen, 1997) the regional context (Jaffe, 1989; Acs et al. 1992, 1994; Feldman, 1994; Feldman and Audretsch, 1999) as well as the international context (Coe and Helpman, 1995, Eaton and Kortum, 1996; see Keller, 2010 for a review of this literature). An alternative method used by empirical research to measure spillovers is to rely on firms' self-reported use of sources of information[148], as available for instance from the CIS[149] to capture

[148] Kaiser (2002a) provides empirical support that these sort of measures are more suitable then using Euclidean technological distance and geographical distance to capture knowledge spillovers.

knowledge spillovers (Cassiman and Veugelers, 2002; Crespi, Criscuolo, Haskel and Slaugther, 2007; Criscuolo, Haskel and Slaughter, 2010;) which is also interpreted by some as a proxy for absorptive capacity (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011; Schmidt, 2010). The resource based literature similarly argues that a part of the firm's capabilities are "based on developing, carrying, and exchanging information through the firm's human capital" (Amit and Shoemaker, 1993) and these being difficult to copy explain why firms can earn "Ricardian rents" (Barney, 1991). So the extent of knowledge spillovers entering and leaving a firm according to this literature is determined by its capabilities namely the ability to absorb as well as to appropriate knowledge.

As argued the amount of knowledge spillovers that leave a firm will depend on its ability to appropriate the technological knowledge it has created (for a review of the major contributions to the appropriability literature see Cohen, 1995; Winter, 2006b and Dosi, Malerba, Ramello and Silva, 2006). Firms in an environment with many spillovers present due to low appropriability have fewer incentives to invest in innovative efforts (Spence, 1984). Intellectual Property Rights have been put in place by regulators to overcome the perceived non-excludability from knowledge which is embodied in innovations[150]. Mansfield (1986), Levin et al. (1987), Cohen et al. (2000) as well as Galende (2006) study the appropriation methods used by firms to protect their innovations and innovative efforts from being copied by other firms and find that they are wide ranging from the use of trademarks, over the use of secrecy to patenting. They also find that these are often complementary in nature. Likewise Teece (1986) had already argued that appropriation is easier if one has invested in "downstream" or other complementary assets, such as manufacturing or marketing channels[151]. The notion of appropriability is also encountered in the related RBV, which points out that an important property of intangible assets which helps to maintain a sustained competitive advantage is that they are difficult to

[149] Janz, Lööf and Peters (2004) and Griffith et al. (2006) in their empirical work have interpreted these as partly demand pull and supply push variables, other literature has used the data on sources of information in the CIS but did not link it directly to any theoretical conceptions.

[150] An extensive literature has subsequently investigated them with mixed findings as to their usefulness (Mansfield, 1981; Levin et al., 1985; Mansfield, 1986; Levin et al., 1987; Cohen et al., 1987; Brouwer and Kleinknecht, 1999).

[151] See for instance Pavitt (1984), Geroski (1992) and Tomlinson (2010) on the role of vertical knowledge spillovers.

copy (Barney, 1991; Newbert, 2007). Teece (1986) however argues that too much protection can be harmful for innovative efforts as firms invest too much in this area rather than focusing on dissemination of knowledge, for instance through cooperation with other firms[152]. Another aspect of appropriation investigated by Saviotti (1998) in particular as well as by Teece (1986) more generally is the role of codification in facilitating dissemination of knowledge, on the other hand tacit knowledge is more appropriable. In any case the general understanding is that a firm that is not able to appropriate returns from its innovative activities is unlikely to carry out such undertakings (Levin et al., 1987; Cohen, 1995; Winter, 2006b). Nevertheless as Dosi, Marengo & Pasquali (2006) conclude from their review of the theoretical and empirical literature in line with the proposition by Teece (1986) there is an optimum level of appropriation beyond which innovative activities start decreasing.

Gonzalez-Alvarez and Nieto-Antolin (2007) show how different protection mechanisms are applicable for different types of knowledge, for example they find that firms with explicit knowledge are more likely to use formal protection and those with tacit knowledge informal protection[153]. They measure appropriation based on a firm survey that asks respondents for their use of protection measures for their innovation. Similarly Levin et al. (1985) and Cohen et al. (1987) measure appropriation based on firms' survey responses about the effectiveness of appropriation methods in protecting their innovation while Arbussa and Coenders (2007) to do so rely on firms' reported investments in appropriation instruments. Cohen, Nelson and Walsh (2000) have performed factor analysis on appropriation methods used and identified three factors[154]. These were interpreted as "capabilities/first movers", "patents" and "secrecy". Their analysis is based on the information about innovation protection methods used by the firms, namely whether firms have used registration of design, trademarks, patents, confidentiality agreements, and copyrights but also whether they have used strategic protection

[152] Hashai and Almor (2008) find empirical evidence for this proposition.
[153] Note however that in the literature review found in the introduction regarding tacit and codified knowledge the conclusion is that there was no clear cut distinction in terms of strategies followed by firms simply because real knowledge is likely to be made up of a mix of these forms of knowledge.
[154] They have used industry mean scores on appropriability mechanisms to generate these.

methods such as secrecy, complexity of design and lead-time advantages. Becker and Peters (2000) with similar information from the Mannheim Innovation Panel 1993 for Germany conduct factor analysis to identify different appropriation strategies used by firms. Their factor analysis though is 'confirmatory' and endorses the existence of separate formal and informal protection methods. Both of these studies though have used information on protection mechanisms for product and process innovation separately. This is possibly not an ideal approach given how difficult they are to distinguish and thus is likely to add explanatory power to the identified factors potentially leading to over-extraction of factors. Similarly to the surveys used by the aforementioned works the CIS provides an extensive set of questions where firms rate the importance of various appropriation methods which have been pointed to by the literature. However the CIS does not cover the use of complementary resources such as 'complementary sales and servicing' and 'complementary manufacturing' as in the survey used by Cohen et al (2000)[155]. So when factor analysing the responses on the importance of methods of protection one could expect to extract a two factor solution, one factor based on formal and another on informal protection methods.

Castellacci (2008) and Griffith, Redding and Van Reenen (2004) date the conception of absorptive capacity back to the works of Gerschenkron (1952) and Abramovitz (1986)[156] who described how technological assimilation at the country level is vital for "catching up"[157]. This is a situation where direct knowledge spillovers (Arrow, 1962; Jaffe, 1986; Levin and Reiss, 1988) are not complete due to the increasing amount and complexity of information available (De Bondt, 1997; Granstrand, Patel and Pavitt, 1997) and the use of appropriation methods mentioned previously. Also at the firm level the need for the right resources to access external knowledge pools or in other words to find and make use of knowledge spillovers, has been recognised. This is what Cohen and Levinthal (1990) have described as "The ability

[155] This data was obtained through interviewing R&D lab managers in the US in 1994.
[156] A similar work by Nelson and Phelps (1966) stipulates that education is essential to keep up with technology progress.
[157] Similar notions can be found in Freeman's (1987) book on Japans innovation system, or see Rogers (2004b) for a recent article on the relationship of absorptive capacity and catching up. Other literature on the importance of absorptive capacity at the national level include Griffith, Redding and Van Reenen (2003, 2004), Kneller and Stevens (2006,2008) and Criscuolo and Narula (2008).

of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends“ which they show to be vital for innovation[158]. They trace the firm’s absorptive capacity back to the organization of its workers absorptive capacity[159]. Furthermore while R&D is useful in generating innovations but R&D also has an indirect effect on innovative activities through building absorptive capacity. This is why Cohen and Levinthal (1989) have coined the term “the two faces of R&D”[160], where past innovative experiences are a sign of the capability “to identify, assimilate and exploit knowledge from the environment”. This highlights that R&D is also useful to firms through indirect learning effects that occur when carrying out R&D. As noted absorptive capacity depends though not only on past innovativeness but also on human capital management (Jansen et al., 2005; Schmidt, 2010). The RBV similarly stresses the role of knowledge embedded in employees and how its coordination is vital in gaining a competitive advantage (Grant, 1996, Kogut and Zander, 1992). Like the evolutionary perspective the resource based perspective points to the path dependence of capabilities (Locket, Thompson and Morgenstern, 2009) such as absorptive capacity. Absorptive capacity helps to acquire information and then needs to be related to what the firm already knows (Zahra and George, 2002)[161].

While absorptive capacity has been identified to be a key component in explaining innovative activities of firms, the exact boundaries and dimensions of absorptive capacity are still being established (Zahra and George, 2002; Bosch, van Wijk and Volberda, 2003). What is clear is that it is the ability to use information from outside the firm for innovative activities. Recent literature (Zahra and George 2002; Arbussa and Coenders, 2007; Fosfuri and Tribo, 2008) suggests that there are two broad dimensions to it. On the one hand there is the ability to scan external information, specifically concerned with acquisition and assimilation of knowledge

[158] So knowledge transfers are clearly not costless and require previous investment into a firm’s resource base (Klevorick et al. 1995, Teece et al. 1997, Cantwell 2005). In an alternative interpretation Carlsson and Eliasson (1994) refer to this as “economic competence” or it can also be interpreted as part of a firm’s dynamic capabilities (Teece and Pisano, 1994): the “ability to exploit business opportunities”.

[159] A concept identified in the field of Psychology related to the ability to learn, dependent on previously acquired knowledge of the individual.

[160] While this sort of thinking may also be somewhat biased in its reliance on R&D figures it provides evidence of the complexity of innovation in that R&D spending cannot be simply equated one to one into the generation of outputs and in that it is cumulative.

[161] Schmidt (2010) provides empirical evidence for the path dependence of absorptive capacity.

or what has been termed "potential absorptive capacity" and on the other hand there is the ability to actually make use of this information which has been termed "actual or realized absorptive capacity" and is specifically concerned with transformation and exploitation of knowledge. Jansen et al. (2005) argue that it is social integration mechanisms (information about transformation and exploitation) that determine how much of the potential absorptive capacity is translated into realized absorptive capacity. According to the literature while for 'potential absorptive capacity' firms need to have the right external linkages to become aware of new information, for 'actual absorptive capacity' they need to be able to relate this information with their past knowledge stock and identify how it can be best commercialized (Teece, 1998). Both of these dimensions of absorptive capacity are understood to act at different stages of the innovation process (Fosfuri and Tribo, 2008).

Cohen and Levinthal (1989, 1990) empirically show that there is a positive relationship between absorptive capacity and the innovative performance of firms (see Veuglers, 1997; Becker and Peters, 2000; Tsai, 2001; Griffith, Redding and Van Reenen, 2003, 2004; Fosfuri and Tribo, 2008; Arbussa, 2007; Nieto and Quevedo, 2005 for further empirical evidence). These studies (Veugelers, 1997; Becker and Peters, 2000; Nieto and Quevedo, 2005; Vega Jurado et al., 2008) have mostly proxied absorptive capacity with past R&D activities or spending, or the existence of a permanent R&D department to reflect past investment into the knowledge stock[162] of firms. Generating an alternative measure Camison and Fores (2010) use confirmatory factor analysis on firm survey data containing self-assessments about their performance relative to competitors along dimension related to their capacity to acquisition, assimilate, transform and apply knowledge. Their work verifies the existence of two dimension of absorptive capacity, namely potential and realized absorptive capacity. The article by Becker and Peters (2000) mentioned when discussing the empirical identification of appropriation methods also uses confirmatory factor analysis on information about types of knowledge sources used by firms (institutional, suppliers and customers), which they interpret to be

[162] Kogut and Zander (1992): knowledge based view of the firm.

technological opportunities[163] similar to the work of Cohen and Levinthal (1990). However for the later paper this information is based on the assessment of "the importance of external sources of knowledge to technological progress in a line of business". So the Cohen and Levinthal's (1990) measures are industry specific in line with the definition of technological opportunities rather than as in the Becker and Peters (2000) firm specific. Becker and Peters (2000) acknowledge however that these measures are precursors to absorptive capacity. The technological opportunities they confirm stem from competitors and customers, suppliers and scientific organizations.

The CIS does not solicit information about the existence of a permanent R&D department[164] or the amount of past R&D spending in the past or at the start of the survey, however it contains data on the importance of certain knowledge sources for innovation. Recent empirical work (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011; Schmidt, 2010) has interpreted the use of such information sources reported in the CIS as evidence of firms having absorptive capacity and thus used it as a proxy for it, also because no more appropriate measure exists in the CIS. This approach is rationalized on the ground that to be able to take advantage of certain types of information firms must have the required resource, absorptive capacity to do so to. This is because knowledge spillovers as has already been pointed out by Arrow (1962) are not costless and due to the increasing complexity and amount of knowledge this observation has become even more relevant today. In line with this argument Fagerberg and Verspagen (2002) found evidence that the costs of diffusion have increased. In this context the conceptualization of absorptive capacity as an essential firm capability (Cohen and Levinthal, 1989, 1990) should no longer come as much of a surprise.

[163] In their paper only the translation of the technological opportunities into innovation is understood to represent absorptive capacity, which in the literature has also thus been termed the "actual or realized" absorptive capacity. They themselves capture absorptive capacity using "proxies" based on continuity of R&D and existence of R&D labs. Note though that technological opportunities are not related to the amount of information used by firms for innovation but to the amount that is thought available to them in their respective industry.

[164] This information was present in the CIS 3 though, specifically whether R&D activities were of permanent or occasional nature.

Harris and Li (2009) point out the advantage of using this sort of data to generate a measure of absorptive capacity over the use of past R&D spending as proxy is that absorptive capacity is understood to be exogenous being build up over time, using past R&D as absorptive capacity proxy makes it potentially endogenous. Likewise this sort of measure is biased towards manufacturing where basic research from R&D is more relevant than in the service sector where other sort of innovative activities are more important which will however also lead to the firms increasing their absorptive capacity. A measure based on firm's used information sources for innovation is thus likely to more accurately measure this ability.

As has been argued absorptive capacity and appropriation are important resources for capturing knowledge spillovers which are so vital to innovation. The CIS does not allow to directly identify the exact linkages involved in knowledge spillovers, it also neglects organisational practices and related human resource management (Bloch, 2007) which are vital in understanding absorptive capacity. Still it provides researchers with the great opportunity using factor analysis to characterise and proxy for firms' appropriation and absorptive capacity and thus to gauge knowledge that enters them and the extent to which they are able to retain knowledge they have generated.

3.9. Appendix - Results Absorptive Capacity, Appropriability

Table 3.72, Sample Size for Factor Analysis Absorptive Capacity, Appropriability

	CIS 4	CIS 5
Total	16,008	14,595
Absorptive Capacity	15,427	12,552
Appropriation	15,403	12,780

The generation of an absorptive capacity measure and an appropriation measure is carried out for the whole sample available from the CIS. This can though only be done for the CIS 4 and the CIS 5 as the CIS 6 does not contain responses on 'importance of information sources for innovation' for 'non-innovation active' firms and it also no longer includes the question on the importance of protection methods used[165]. The rationale behind this is that firms considered 'non-innovation active'[166] per CIS 6 definition do not necessarily possess no absorptive capacity.

Table 3.73, Correlation Matrix Appropriation Methods for all firms, CIS4

	Design	Trademarks	Patents	Confidentiality	Copyright	Secrecy	Complexity	Leadtime
Design								
Trademarks	0.89							
Patents	0.91	0.88						
Confidentiality	0.77	0.76	0.79					
Copyright	0.84	0.84	0.83	0.81				
Secrecy	0.75	0.74	0.76	0.87	0.79			
Complexity	0.78	0.72	0.79	0.79	0.77	0.86		
Leadtime	0.72	0.69	0.73	0.79	0.73	0.84	0.87	

Table 3.74, Correlation Matrix Appropriation Methods for all firms, CIS5

	Design	Trademarks	Patents	Confidentiality	Copyright	Secrecy	Complexity	Leadtime
Design								
Trademarks	0.89							
Patents	0.90	0.88						
Confidentiality	0.76	0.74	0.76					
Copyright	0.85	0.86	0.85	0.80				
Secrecy	0.74	0.71	0.74	0.89	0.75			
Complexity	0.79	0.74	0.79	0.79	0.78	0.82		
Leadtime	0.74	0.71	0.72	0.77	0.72	0.79	0.84	

Let's look at the polychoric correlation matrix for the question about the 'importance of various methods of protection' for firms (tables 3.73 and 3.74). The values of the pair-wise correlations suggest that the various protection methods are not independent from another, it also shows that while correlated the extent of the correlation varies from protection method to protection method. The strongest

165 More accurately this has been changed to reflect actual protection methods applied for, such as trademarks, design registration, patents and copyrights.

166 Those firms that have not introduced wider innovation, process or product innovation during the survey period.

correlations are found among ‘registrations of design’, ‘trademarks’ and the use of ‘patents’, as well as among ‘secrecy’ and ‘confidentiality’. There seem to be no notable differences in correlations among CIS 4 and CIS 5.

For both the CIS 4 and the CIS 5 based on the Kaiser criterion a single principal component factor is retained accounting in both cases for 82% of the combined variance of the rating of these methods of appropriation (tables 3.75 and 3.76) while according to the scree plots (figure 3.32 and 3.33) a one or two factor solution could be retained. For the purpose of measuring appropriation to be used in later analysis the generation of a single factor that explains such a large amount of the variability is ideal in terms of data reduction. The Kaiser Meyer Olhin measure of sampling adequacy of above 90% indicates that the correlation matrix has a “marvellous” sampling adequacy. The uniqueness which is the proportion of the variance not explained by the factors is the largest for ‘lead time advantage’ suggesting that it is the least related to the other appropriation methods. Overall the obtained factor seems to capture well the ‘importance of appropriation methods for innovation’. The past literature (Becker and Peters, 2000; Cohen, Nelson and Walsh, 2000) on the other hand has suggested up to three distinct appropriation strategies, namely formal, informal and marketing. The last one, regarding protection through marketing could not have been identified in any case as it is not part of the question set[167]. Furthermore these findings were made over 10 years ago and for a different systemic setting (Germany and US respectively). When factors were over extracted, that is the cut-off criterion was relaxed to include a second factor, formal methods of protection could be identified as a separate factor from informal methods of protection which is in line with the findings of Becker and Peters (2000) for the Mannheim Innovation Panel 1993 albeit using confirmatory analysis[168]. However this extra factor only explained an additional 7% of the variability in rating of protection methods and has an eigenvalue of roughly over half which is far away from the Kaiser criterion. The

[167] While information about use of marketing is available from the question about the use of innovative inputs they are not set in the context of how useful they are for appropriation.

[168] As noted their and Cohen et al.’s (2000) study have included the information for protection of process and product innovations separately which is very likely to have added to the strength of the factors identified. Given that their distinction is somewhat arbitrary may mean that this sort of approach is inappropriate and has led to more factors being identified.

result thus confirms the idea that appropriation methods are complementary (Mansfield, 1986; Teece, 1986; Levin et al., 1987; Cohen et al., 2000; Galende, 2006) rather than substitutes, at least if looked at from an economy wide perspective. Closely related to appropriation is the distinction of the types of knowledge that should influence the appropriation methods used, that is whether it is codified or tacit[169]. It has been argued that knowledge mostly exhibits mixed properties (Johnson, Lorenz and Lundvall, 2002; Toedling, Lehner and Kaufmann, 2009) suggesting that appropriation methods need to be comprehensive as identified in this factor analysis. The last conclusion is to be treated with caution though as knowledge and innovation is not one and the same thing, though as detailed in the next chapter knowledge capital is a prerequisite for generating innovations.

[169] See Saviotti (1998) as well as the discussion in the knowledge spillover literature review appendix (3.8) but also in the section on knowledge in the literature review in the introduction where tacit and codified knowledge are compared.

Table 3.75, Factor Analysis Appropriation Methods for all firms CIS4

	Loadings Factor 1		Uniqueness	KMO
Design Registrations	0.92		0.15	0.92
Trademarks	0.90		0.19	0.93
Patents	0.92		0.15	0.93
Confidentiality	0.91		0.18	0.94
Copyright	0.91		0.17	0.96
Secrecy	0.91		0.17	0.92
Complexity	0.91		0.18	0.91
Leadtime	0.88		0.23	0.93
		next factor		
Eigenvalues (1st, 2nd, …)	6.58	0.55		
Explained variability				
before rotation	0.82	0.07		
after rotation	0.82		Total KMO	0.93

Table 3.76, Factor Analysis Appropriation Methods for all firms CIS 5

	Loadings Factor 1		Uniqueness	KMO
Design Registrations	0.92		0.15	0.93
Trademarks	0.90		0.18	0.93
Patents	0.92		0.15	0.94
Confidentiality	0.90		0.19	0.91
Copyright	0.92		0.16	0.96
Secrecy	0.89		0.21	0.90
Complexity	0.90		0.18	0.93
Leadtime	0.87		0.25	0.94
		next factor		
Eigenvalues (1st, 2nd, …)	6.53	0.55		
Explained variability				
before rotation	0.82	0.07		
after rotation	0.82		Total KMO	0.93

Figure 3.32, Scree plot Rating of Appropriation Methods CIS 4

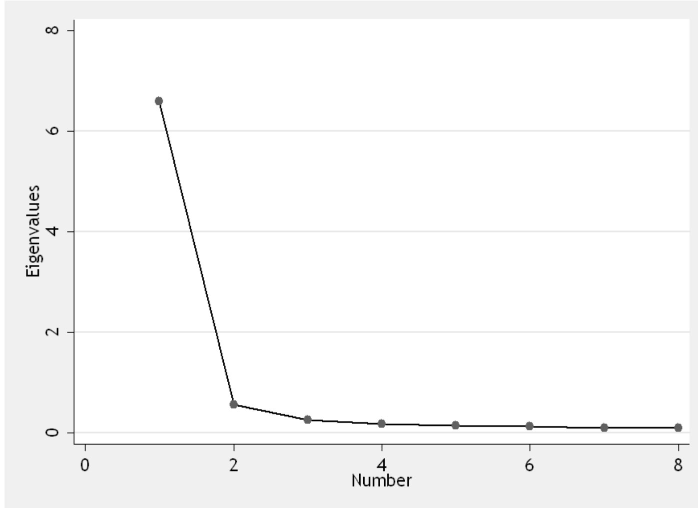


Figure 3.33, Scree plot Rating of Appropriation Methods CIS 5

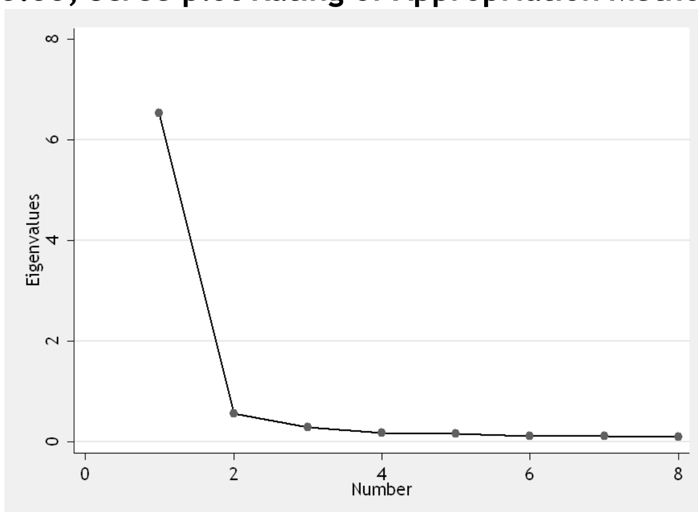


Table 3.77 shows the variation of the identified factor across the main UK regions, England has the highest average of the appropriation measure, next is Wales and then Scotland followed by Northern Ireland in last place however these deviations are hardly noteworthy. The appropriation index also increases with firms size (table 3.78), larger firms from a theoretical perspective due to having more resources at their disposal for generating innovative outputs[170] can be expected to make use of more appropriation methods[171]. Likewise they are more visible in the market and thus have to put larger efforts into protecting their innovations. It is also more

[170] See Cohen (1995) as well as the theoretical discussion and results in the next chapter for evidence.
[171] There also exists evidence in the IP literature that small firms are less likely to apply for patents (Brouwer and Kleinknecht, 1999; Cohen et al. 2000).

worthwhile and feasible for larger firms to do so given the larger number of units of output over which they can recuperate their appropriative efforts. In light of the finding that too much appropriation may be harmful for innovative activities as identified in the literature reviewed by Dosi, Malerba, Ramello and Silva (2006), the result that larger firms attach considerable more importance to appropriation methods provides some grounds for continued antitrust policy. On the other hand they are likely to have more knowledge capital that needs appropriation. Variations across industries (table 3.78) are more substantial, with the 'computer industry' and the 'manufacture of electrical and optical equipment' having the highest values for the appropriation index while 'retail trade, hotels and restaurants' have the lowest appropriation index. These results confirm that while types of protection methods are complementary[172] the extent to which they are used in different industries varies to some extent related to their propensities to innovate.

Table 3.77, Percentile of mean of Appropriation by regions and N

	Percentile		Sample sizes	
	CIS 4	CIS 5	CIS 4	CIS 5
England	0.51	0.50	12,339	11,189
Wales	0.48	0.49	1,090	1,128
Scotland	0.47	0.47	1,236	1,204
Northern Ireland	0.45	0.47	1,343	1,074

Table 3.78, Percentile of mean of Appropriation by sizeband and N

	Percentile		Sample sizes	
	CIS 4	CIS 5	CIS 4	CIS 5
9-19	0.45	0.46	5,279	4,710
20-49	0.50	0.50	3,668	3,291
50-99	0.58	0.58	2,489	2,079
100-199	0.63	0.61	1,152	1,034
200-499	0.67	0.69	1,996	1,945
500+	0.70	0.71	1,624	1,534

[172] Based on the single appropriation factor identified.

Table 3.79, Percentile of mean of Appropriation by division and N

	Percentile		Sample sizes	
	CIS 4	CIS 5	CIS4	CIS5
Mining & Quarrying	0.49	0.51	197	53
Manufacturing of food, clothing, wood, paper, publish & print	0.56	0.58	1,437	1,434
Manufacturing of fuels, chemicals, plastic metals & minerals	0.61	0.65	1,904	2,116
Manufacturing of electrical and optical equipments	0.76	0.79	666	491
Manufacturing of transport equipments	0.68	0.71	403	260
Manufacturing not elsewhere classified	0.62	0.58	515	363
Electricity, gas & water supply	0.39	0.64	36	65
Construction	0.40	0.41	1,613	1,028
Wholesale trade (incl cars & bikes)	0.51	0.48	1,342	1,325
Retail trade (excl cars & bikes)	0.38	0.41	1,547	936
Hotels & restaurants	0.37	0.35	991	877
Transport, storage	0.43	0.41	1,058	1,120
Post & Courier activities	0.48	0.45	154	77
Telecommunications	0.63	0.72	178	60
Financial intermediation	0.54	0.52	673	503
Real estate	0.41	0.41	416	618
Renting of Machinery and Equipment	0.45	0.40	284	272
Computer and Related Activities	0.79	0.77	439	515
Architectural and engineering activities	0.60	0.62	436	522
Technical testing and analysis	0.62	0.59	154	49
Other business activities	0.47	0.50	1,765	1,909

Again as for appropriation methods lets first have a look at correlation matrix across the questions on the 'importance of sources of information' (tables 3.80 and 3.81). The values of the pair-wise correlations suggest that the use of various information sources is not independent from another, it also shows that while correlated the extent of the correlation varies from information source to information source used. The highest correlations are observed among use of information from 'customers' and 'competitors' as well as information from 'associations' and 'standards'. As for appropriation methods no major differences in the correlations can be observed among the CIS 4 and the CIS 5.

Table 3.80, Correlation Matrix Information Sources for all firms, CIS4

	Internal	Suppliers	Customers	Competitors	Specialized	HE	Public	Events	Publications	Associations	Standards
Internal											
Suppliers	0.72										
Customers	0.75	0.75									
Competitors	0.67	0.68	0.83								
Specialized	0.60	0.60	0.57	0.59							
HE	0.50	0.48	0.49	0.50	0.68						
Public	0.49	0.49	0.52	0.53	0.67	0.81					
Events	0.59	0.60	0.63	0.63	0.52	0.55	0.56				
Publications	0.56	0.60	0.59	0.58	0.55	0.59	0.60	0.71			
Associations	0.57	0.61	0.63	0.61	0.59	0.59	0.64	0.63	0.77		
Standards	0.61	0.64	0.66	0.62	0.62	0.59	0.63	0.61	0.72	0.81	

Table 3.81, Correlation Matrix Information Sources for all firms, CIS5

	Internal	Suppliers	Customers	Competitors	Specialized	HE	Public	Events	Publications	Associations	Standards
Internal											
Suppliers	0.69										
Customers	0.73	0.70									
Competitors	0.68	0.64	0.82								
Specialized	0.60	0.55	0.55	0.57							
HE	0.50	0.45	0.47	0.49	0.70						
Public	0.50	0.46	0.50	0.53	0.69	0.82					
Events	0.59	0.55	0.60	0.60	0.53	0.56	0.57				
Publications	0.57	0.55	0.54	0.58	0.57	0.59	0.62	0.68			
Associations	0.55	0.58	0.61	0.62	0.58	0.59	0.65	0.61	0.75		
Standards	0.60	0.60	0.65	0.62	0.59	0.57	0.63	0.59	0.69	0.79	

Factor analysis of the ‘importance of sources of information for innovation’ question suggests to retain one factor according to the Kaiser criterion which explains around 65% of the variability of the question set for the CIS 4 and 64% for the CIS 5 (table 3.82 and table 3.83). Actually 2 factors should be retained for the CIS5 according to the Kaiser criterion, since the eigenvalue is 1.03 for this second factor. Looking at the scree plots (figures 3.34 and 3.35) however either a one factor or a three factor solution is appropriate. For theoretical reasons explained below only one factor is kept, as such a confirmatory approach is followed here. The Kaiser Meyer Ohlin measure of sampling adequacy is above 90% here indicating that the correlation matrix has a “marvellous” sampling adequacy. The uniqueness measure is highest for use of ‘higher education’ and ‘specialized knowledge’ confirming that indeed their variability may be better explained by introduction of a second factor. According to the literature strictly two or loosely four dimension of absorptive capacity have been identified. Notably the distinction into potential and realized absorptive capacity in the literature[173] one translating, dependent on the degree of efficiency with which it is used, into the other. As the factor representing this information is to be used as a general measure of absorptive capacity and the question on which the factor analysis is based do only concern actual innovative activities it is difficult to relate them to the potential absorptive capacity of the firms, thus a single factor solution is retained. As noted this interpretation is based on the idea that if firms rate certain information sources as important they must possess the required skills to do so as this is not a costless process (ie no free knowledge spillovers exist), that is they have absorptive capacity (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011; Schmidt, 2010).

[173] See for instance Zahra and George (2002) and the discussion in section (3.8) of this chapter; realized absorptive capacity is however related to firm internal organisation (see for instance Jansen et al. 2005), which as discussed in the data chapter are not captured by the survey. Though with a two factor solution one could argue that potential absorptive capacity (acquisition and assimilation) is related to specialized sources of information and realized absorptive capacity (transformation and exploitation) to market sources of information.

Table 3.82, Factor Analysis Sources of Information for all firms CIS4

	Loadings Factor 1		Uniqueness	KMO
Internal	0.79		0.37	0.95
Suppliers	0.81		0.34	0.96
Customers	0.84		0.30	0.90
Competitors	0.82		0.33	0.91
Specialized	0.79		0.38	0.95
HE	0.76		0.42	0.90
Public	0.78		0.40	0.91
Events	0.79		0.37	0.96
Publications	0.82		0.33	0.94
Associations	0.84		0.29	0.93
Standards	0.85		0.28	0.94
		next factor		
Eigenvalues (1st, 2nd, …)	7.19	0.99		
Explained variability				
before rotation	0.65	0.09		
after rotation	0.65		Total KMO	0.93

Table 3.83, Factor Analysis Sources of Information for all firms CIS 5

	Loadings Factor 1		Uniqueness	KMO
Internal	0.80		0.37	0.95
Suppliers	0.77		0.41	0.96
Customers	0.81		0.34	0.89
Competitors	0.81		0.34	0.92
Specialized	0.79		0.38	0.96
HE	0.76		0.42	0.89
Public	0.79		0.38	0.90
Events	0.78		0.39	0.96
Publications	0.81		0.34	0.94
Associations	0.84		0.30	0.93
Standards	0.84		0.30	0.94
		next factor		
Eigenvalues (1st, 2nd, …)	7.05	1.03		
Explained variability				
before rotation	0.64	0.09		
after rotation	0.64		Total KMO	0.93

Figure 3.34, Scree plot Rating of Sources of Information CIS 4

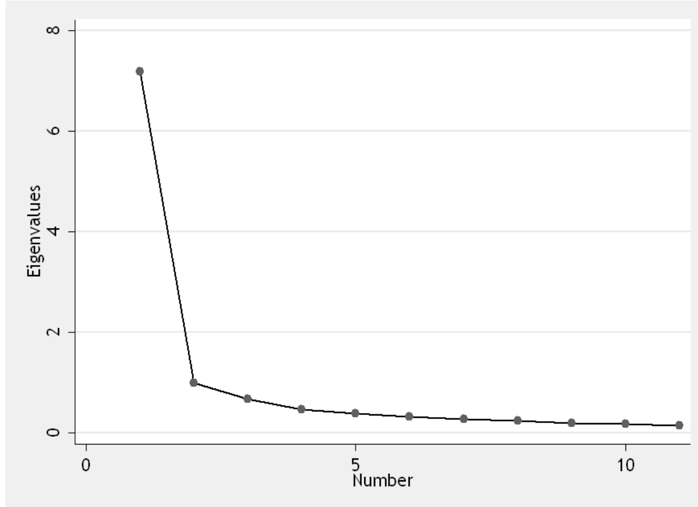
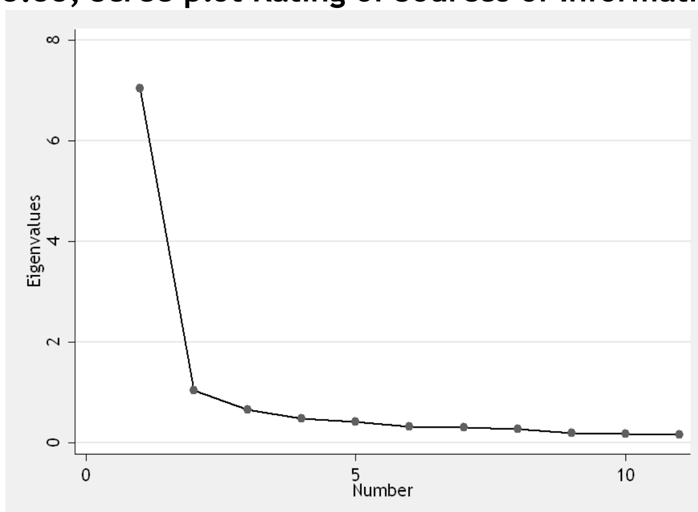


Figure 3.35, Scree plot Rating of Sources of Information CIS 5



As for appropriation, absorptive capacity is highest for England and lower for the other non-English regions (table 3.84). However these differences again appear negligible. Variations across industries (table 3.85) are likewise more pronounced, the 'computer industry' and the 'manufacturing of electrical and optical equipment' having the highest values while 'retail trade, hotels and restaurants' have the lowest again very similar to what is observed for the appropriation measure. The absorptive capacity index also increases with firms' size (table 3.86), this can been interpreted as evidence that absorptive capacity is something that resides in individual workers and their organization and thus absorptive capacity "adds up" or even "multiplies" (Cohen and Levinthal, 1990). At the same time it shows that while larger firms find appropriation methods more important this is likely related to their ability of transforming and exploiting knowledge which requires considerable innovative efforts in the past.

Table 3.84, Percentile of mean of Absorptive Capacity by regions

	Percentile		Sample sizes	
	CIS 4	**CIS 5**	**CIS 4**	**CIS 5**
England	0.50	0.50	12,339	11,189
Wales	0.47	0.50	1,090	1,128
Scotland	0.50	0.49	1,236	1,204
Northern Ireland	0.49	0.49	1,343	1,074

Table 3.85, Percentile of mean of Absorptive Capacity by divisions

	Percentile		Sample sizes	
	CIS 4	**CIS 5**	**CIS 4**	**CIS 5**
Mining & Quarrying	0.49	0.48	197	53
Manufacturing of food, clothing, wood, paper, publish & print	0.53	0.57	1,437	1,434
Manufacturing of fuels, chemicals, plastic metals & minerals	0.56	0.58	1,904	2,116
Manufacturing of electrical and optical equipments	0.70	0.72	666	491
Manufacturing of transport equipments	0.60	0.63	403	260
Manufacturing not elsewhere classified	0.56	0.57	515	363
Electricity, gas & water supply	0.43	0.62	36	65
Construction	0.46	0.45	1,613	1,028
Wholesale trade (incl cars & bikes)	0.53	0.47	1,342	1,325
Retail trade (excl cars & bikes)	0.40	0.42	1,547	936
Hotels & restaurants	0.37	0.37	991	877
Transport, storage	0.44	0.44	1,058	1,120
Post & Courier activities	0.46	0.48	154	77
Telecommunications	0.64	0.57	178	60
Financial intermediation	0.58	0.56	673	503
Real estate	0.44	0.46	416	618
Renting of Machinery and Equipment	0.49	0.44	284	272
Computer and Related Activities	0.69	0.67	439	515
Architectural and engineering activities	0.65	0.64	436	522
Technical testing and analysis	0.64	0.64	154	49
Other business activities	0.47	0.54	1,765	1,909

Table 3.86, Percentile of mean of Absorptive Capacity for sizebands

	Percentile		Sample sizes	
	CIS 4	**CIS 5**	**CIS 4**	**CIS 5**
9-19	0.45	0.46	5,279	4,710
20-49	0.51	0.50	3,668	3,291
50-99	0.58	0.58	2,489	2,079
100-199	0.59	0.60	1,152	1,034
200-499	0.64	0.64	1,996	1,945
500+	0.67	0.68	1,624	1,534

4. Determinants of Innovation

4.1. Introduction

In this chapter innovation is analysed as an input output type process. This perspective has been first formalized in the R&D production function of Pakes and Griliches (1984), based on which Crepon, Duguet and Mairesse (1998) built a structural model that can be estimated using firm level data. While it has been argued that this sort of approach neglects important feedback effects inherent in the innovation process (Kline and Rosenberg, 1986) it allows to identify what can be termed the determinants of innovation. The aim of the chapter is hence to draw out the extent to which various factors identified by the literature and available from the UK CIS influence firms to carry out R&D and innovate as well as to confirm that innovative activities have a positive impact on firm productivity.

This work adds to the empirical literature by providing evidence from recent UK CIS surveys. This is important as the only similar work based on the UK CIS 3 was undertaken by Griffith, Huergo, Mairesse and Peters (2006) with a substantially smaller sample (1,904 observations compared to 13,836 and 11,428 used herein). The reason for this is that they carried out a cross country comparison and hence needed to restrict themselves to comparable samples. This meant discarding all firms that had less than 20 employees as well all those belonging to the service sector. So this study represents a major contribution in that it is based on a much more extensive sample specifically including the service sector and smaller firms. It is thus much more representative of the UK economy. Furthermore this work distinguishes itself by making use of the comprehensive measures of absorptive capacity and appropriability generated in the past chapter. These have not been previously used in the literature following the CDM methodology and due to their continuous nature allow to test for decreasing returns to scale to these two properties. Since these indexes could not be generated for the CIS 6 it is excluded from the subsequent analysis. Unlike the aforementioned paper by Griffith et al. (2006) it is not constrained to the use of variables in the CIS that are comparable across countries. Another contribution is the inclusion of industry concentration and market share as explanatory variables. While the former has been used by Castellacci (2011) his measure was interpolated from the CIS data using the contained weights rather than being based on actual population data. Instead in this chapter these variables are derived from actual population data obtained from the ARD. Also Castellacci's (2011) analysis is conducted for Norway which due to its small size and other factors is likely to have a considerably different competitive environment then the UK and thus lead to differing results of the impact of industry concentration.

The econometric implementation in its first stage involves a Heckman (1979) model to estimate the effect of the determinants of whether firms carry out R&D and how much they carry out conditional on having positive (observable) R&D spending. The Heckman model allows to account for sample selection since firms that report R&D spending are a non-random sub-sample. In a second stage[174] predicted R&D spending from the first stage which is a proxy of a firm's knowledge capital together with other factors is used as explanatory variable in estimating the likehood of introducing innovative outputs. R&D spending is instrumented in this stage using identifying restrictions as it is believed to be an endogenous determinant of innovation. Likewise the predicted likehood of introducing an innovation is then used to explain firm level productivity. Similarly propensity to innovate is instrumented in this third stage as it is likely to be endogenous in explaining productivity.

The structure of this chapter is as follows. The second section is a review of factors that are believed to explain firms' innovative activities based on theoretical grounds and notes if these have been confirmed empirically. The subsequent section then describes the theoretical framework presented by CDM which is followed by the fourth section that contains details of its empirical implementation. Next is the data section providing tabulations of the variables'

[174] From now on the term "stage one" if used refers to the Heckman model explaining propensity to carry out R&D and amount of spending on R&D, the "second stage" refers to the probit model explaining innovation while the "third stage" refers to the model explaining firm productivity. The term "step" is used to refer to the two parts in the Heckman model that is estimation of the propensity to carry out R&D propensity and estimation of the size of R&D carried out conditional on performing R&D. Note though that since these two steps in the Heckman model are estimated simultaneously it is not quite appropriate to speak of steps as such.

means under scrutiny and pointing to differences across surveys. This section also specifies the motivation for the use of the appropriation and the absorptive capacity measure generated in the previous chapter as well as explaining what other explanatory variables are to be included in the model specifications. The sixth section contains the results and is followed by the section that concludes this chapter.

4.2. Literature Review

A highly disputed observation by Schumpeter was regarding the role of industry structure on innovative activities. He argued that ex-post expectation of market power and thus profits from appropriating the returns of innovative outputs would induce R&D spending. Ex-ante market power on the other hand is expected to make it easier to obtain finance either through retained profits or from creditors (Geroski, 1990; Blundell, Griffith and Van Reenen, 1999). Blundell, Griffith and Van Reenen (1999) however point out that there also exist many theoretical reasons for the relationship between market share and innovative activity to be negative. The second point put forth by Schumpeter regarding market structure was that in oligopolistic settings firms are more likely to innovate due decreased uncertainty about their opponents reactions. While Arrow (1962) shows that a firm under competition has larger incentives to innovate. It also has been argued that x-inefficiency may cause large, monopolistic firms to be less flexible in adjusting their procedures[175] and thus be less likely to innovate (Acs and Audretsch, 1987; Klepper, 1996; Cohen and Klepper, 1996). Meanwhile Geroski (1991) contends that industry concentration is observable but not necessarily a fundamental driver of innovation, pointing out that effects of concentration work through the opposing forces of technological opportunity and appropriability. In fact it is believed that innovation can itself stimulate industry concentration as innovators may become dominant in their industry (Cohen, 1995). Arguments about the sign of the relationship between industry concentration and the involvement in innovation thus run both ways, empirically it is found to be a positive or U type relationship

[175] A more thorough review of the theoretical arguments of the relationship between market structure and innovation is presented by Van Cyseele (1998).

(Scherer, 1965; Levin, Cohen and Mowery,1985) that may or may not be significant (Mohnen and Mairesse, 2010). Likewise market share has been observed to have a positive correlation with innovative activities (Crepon, Duguet and Mairesse, 1998; Blundell et al., 1999).

Technological opportunities[176] (see Nieto and Quevedo, 2005; for a review of this literature) and the closely related market opportunities (Schmookler, 1966) are important determinants of innovative activities. The latter is the knowledge available from industries, science and other private and government institutions relevant to the technology in a certain industry (Klevorick et al. 1995). On the other hand technological opportunities are a measure of how easily technological advances can be achieved in a certain industry, dependent on the relation between industry knowledge and the science base (Dosi,1988,1982 , 1988; Nelson and Winter, 1982). The systemic literature similarly highlights the importance of the knowledge firms have access to through the networks they are part of (Edquist, 2005; Cooke, 2006) and which can thus be used by the firm for its innovative activities. According to the theory of networks, closeness in terms of technological or geographical distance facilitates knowledge transfers (Powell and Grodal, 2005). The agglomeration effects (Baptista and Swann, 1998; Black and Henderson, 1999) proximity leads to are discussed in the knowledge spillover literature and have been shown important determinants of innovative activities (Jaffe, 1986; Levin and Reiss, 1988; Griliches, 1992)[177]. Spillovers occur due interactions of employees with customers, competitors and suppliers as well as being the result of common labour pools (Harris, Li and Trainor, 2006).

As argued in the previous chapter[178] to make use of spillovers and technological opportunities one needs to have the right resources, that is absorptive capacity (Cohen and Levinthal, 1989). This recently popular conception moves the focus away from knowledge available to a firm or industry. Instead it highlights that technological opportunities are dependent on the capabilities that firms possess

[176] Geroski (1990) criticizes that the notion of technological opportunities is vague and empirical implementations are sample dependent.
[177] Also see discussion in section 4.2.
[178] Appendix 3.8.

which are not just related to industry membership but as the RBV argues are firm specific. Empirically Levin et al. (1985), Cohen et al. (1987) and Cohen and Levinthal (1990) find evidence of a positive relationship between absorptive capacity and R&D activities, while Lhuillery (2011) finds evidence that knowledge from competitors can also deter from innovative activities. It is not only the absorbed knowledge but also the outgoing knowledge that impacts on innovative activities. For an industry this depends on its appropriability conditions for a firm it depends on the appropriation instruments used and their effectiveness. In an industry where appropriability conditions are poor the amount of R&D carried out is expected to be less due to decreased incentives (Spence, 1984) at the same time incoming spillovers allow to reduce one's own R&D (Levin and Reiss, 1988). Empirical studies on the subject (Jaffe, 1986, 1988, 1989; Levin and Reiss, 1988; De Bondt, 1997; Nieto and Quevedo, 2005; Arbussa and Coenders, 2007) have found evidence for the proposition of a positive relationship between appropriability and innovative activities while de Bondt (1997) finds that there is a certain optimum level of appropriation above which innovative activities start decreasing and this is confirmed by the literature review of Dosi, Marengo and Pasquali (2006).

Spillovers as stressed by the agglomeration literature (see van der Panne, 2004 for a review) are often specific to certain regions, thus they are also termed localised knowledge spillovers (see Harris, 2011 for a review). Indeed as Castellacci (2008) in a review of the literature notes regional clustering of innovation is evident. However this is due to localization of spillovers, that is it is a result rather than a cause of innovation. In other words it is the characteristics of firms and knowledge available in the region that influence innovation (Castellacci, 2008). Feldman (1999) points out the difficulty of conceptualizing the regional dimension: "pre-existing patterns of technology related activities make it difficult to separate spillovers from the correlation of variables at the geographic level". Nevertheless empirical applications exist, notably Jaffe, Trajtenberg and Henderson (1993) find evidence that spillovers are often localized and their importance decreases with distance. Fritsch and Franke (2004) confirm that regional differences in innovative activities are due to differences in spillovers. Johansson and Lööf (2008) show that while some regions have a smaller share of innovative firms the fundamental properties of innovative firms are independent of where they are located, which lends support to the notion that location only has an indirect impact on innovative activity as such. On the other hand the regional innovation systems literature argues that institutional characteristics and their relationships specific to a region influence innovative undertakings within them (Cooke, 1992, 2006; Cooke, Uranga and Etxebarria, 1997; Asheim and Isaksen, 1997, 2002). Empirical evidence for regions' systemic impact is found by Srholec (2010). Thus the region may have an indirect effect through spillovers present and a more direct effect through the systemic environment on innovative activity.

Fritsch (2000) in a review of the literature regarding the location of R&D activities identifies three hypotheses, one of them is that new processes are developed first in the central and then in the peripheral regions. Secondly those central regions have higher propensity to carry out R&D as well as higher R&D spending, and lastly that central regions are more suited for introducing product innovations. However he concedes that that empirical evidence for these propositions is inconclusive. Likewise Harris (1988b) notes that the "branch plant" economy theory stipulates that the bulk of innovative activities is carried out close to headquarters whereas plants in the periphery are geared towards assembly and sub-assembly which only provide potential for process innovations which are less knowledge intensive[179]. There is evidence that successful plants are taken over by larger firms and these concentrate their innovative efforts in the South East of England (Harris, Li and Trainor, 2006). Thus these peripheral regions are thought at a disadvantage in terms of knowledge pools available to them and hence expected to exhibit less innovative activities[180].

Schumpeter's observation that large firms have big R&D departments was interpreted by the innovation literature of the 70s and 80s as a suggestion of a positive relationship between firm size and R&D spending for which empirical support has been found (see Cohen, 1995 for a review of this evidence). Support for

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[179] He also relates this to the product life cycle model in which at the later expansion stage only process innovations take place. A similar idea can be found in Krugman's (1991) model of industrial differentiation among "core" and "periphery" in an economy.

[180] Harris (1988a) identifies Northern Ireland to be negatively effected in its innovative performance as a result.

this postulated relationship was further added by the observation that small firms are less likely to have formal R&D taking place (Schmookler, 1959; Kleinknecht, 1987; Pavitt, Robson and Townsend, 1987, 1989)[181]. One rational provided for this relationship is that large firms have an advantage in finding creditors for their innovative undertakings (Hall, 2002a), another is that large firms are able to recover their costs over a larger amount of units sold (Cohen and Klepper, 1996). They are also more capable to internalise R&D spillovers (Cohen et al., 1987; Acs and Audretsch, 1987; Cohen, 1995). Lastly the complementarity of innovative activities and between external and internal R&D may also favour larger firms that have a marketing department and various knowledge sourcing opportunities (Mowery and Rosenberg, 1979; Teece, 1986; Cassiman and Veuglers, 1998). Thus the size of a firm proxies for the ability to appropriate as well as growth potential and technological opportunities due to diversification (Cohen and Klepper, 1996; Klepper, 1996). However it has been found that smaller firms have larger R&D productivity possibly as a result of inefficient bureaucracy in larger firms (Cohen and Klepper, 1996) furthermore large firms are more often process rather than product innovators which is less R&D capital intensive (Harris, Li and Trainor, 1995, 2006). Including these arguments is thought to explain that the relationship between size and R&D spending is generally found to be an inverted U shape (Cohen, 1995; Harris, Li and Trainor, 2006).

Another firm property correlated with its innovative activities is the propensity to export[182]. However causality between the two has not been firmly established. Cassiman and Martinez-Ros (2004) for instance argue that product innovation which effects productivity is necessary for entering foreign markets. This argument is in line with the product life cycle hypothesis of innovation by Vernon (1966). Likewise Harris and Li (2009) contend that in order to gain access to a foreign market one needs to have relevant expertise to be able to make products suitable for foreign market conditions. There are also rationales in favour of the reverse direction of causality. One of them is that once a firm exports it has access to knowledge from

[181] The underreporting is not as extreme as suggested by this research according to evidence presented by Tether, Smith and Thwaites (1997) and Tether (1998), specifically because the impact of small firms innovations tends to be less economically significant.
[182] This is based on the notion that in order to stay competitive one needs to keep innovating (Krugman, 1979).

foreign markets which in turn would stimulate innovative activities at home (Del Canto and Gonzalez, 1999; Rogers, 2004b; Keller, 2010)[183]. Exporting through extending markets a firm can sell to is also an indicator of its growth potential which provides appropriation incentives (Harris and Li, 2010). Looking at past empirical literature on this link suggests that results are dependent on context, specifically the country and type of innovative efforts discussed as well as industry and firm size[184] (Posner, 1961; Soete, 1987; Fagerberg, 1988; Dosi, Pavitt and Soete, 1990; Zhao and Li, 1997). Regarding the appropriability potential of export markets Bernard and Jensen (1999) find that firms that export do not outperform non-exporting firms in terms of growth rates. Lachenmaier and Woessmann (2006) on the other hand find evidence for the endogenous nature of exporting, admitting though that this is based on their exogeneity assumption used. Similarly Harris and Li (2010) using the CIS 4 find that the relationship runs both ways but concede that the relationship is generally weak. Eliasson, Hansson and Lindvert (2011) finds that once entry has taken place no learning through exporting takes place, though this study applies to SMEs only. There hence seems to exist no consensus on the effect of exporting on innovative activities.

The ownership of companies is another factor considered to influence the innovative behaviour of firms. One aspect to ownership is whether a company is home or foreign owned. The branch plant economy theory mentioned earlier suggests that foreign companies would carry out the bulk of their R&D at home. On the other hand it has recently been recognised that due to increasing complexity of outputs and markets, products need to be adapted to demand conditions which vary across markets, this tailoring through R&D is best conducted within the respective markets (Narula and Zanfei, 2005). There is also research that shows that MNCs "use their foreign R&D units to access local academic resources" as Raffo, Lhuillery and Miotti (2008) note (also see Narula and Zanfei, 2005 for details of this research and Keller, 2010). Bishop and Wiseman (1999) review some of the empirical evidence for the UK related to the effect of foreign ownership on innovative activities and find it to be inconclusive before they turn to look at their sample of

[183] In line with this are the endogenous growth models put forth by Grossman and Helpman (1989, 1990) and Young (1991).
[184] Harris and Li (2009) argue that the lack of clear empirical evidence is due to data and econometric issues.

UK defence firms where foreign ownership has a negative impact. Likewise while Love and Roper (1999) find a negative effect of foreign ownership on innovativeness for UK firms in 1995, Love, Ashcroft and Dunlop (1996) found a positive relationship for Scottish manufacturers. Using the CIS 2 and CIS 3 matched with the Who owns Whom (WoW) database[185] Frenz and Ietto –Gillies (2007) find related evidence that multi-nationality has a positive impact on innovative outputs. Similarly Veuglers (2005) conclude that for the UK foreign ownership has a positive impact on R&D spending[186] pointing to the role of multinationals.

Cooperation for innovation allows to internalize spillovers, to spread risks and costs and to use complementary assets of other firms (De Bondt, 1997; Hagedoorn, Link and Vonortas, 2000; Caloghirou, Ioannides and Vonortas, 2003; Mairesse and Mohnen, 2010). Malmberg and Power (2005) state: "innovations predominantly occur as a result of interactions between various actors, rather than resulting from the creative act of the solitary genius". Cassiman and Veugelers (2002) find empirical evidence that spillovers and appropriability play an important role in the decision to cooperate on R&D[187]. Similarly Schmidt (2005) provides empirical evidence that cooperation helps to internalize spillovers. Furthermore Becker and Dietz (2004) find empirical evidence that R&D cooperation is indeed used to complement internal resources and stimulates innovation inputs and outputs. De Faria, Lima and Santos (2010) using the Portuguese CIS find that cooperation is seen as complementary by firms that are highly innovation active, whereas the research of Edquist, Eriksson and Sjogren (2000) and Dachs, Ebersberger and Pyka (2008) concludes that reasons for cooperation are dependent on the systemic context. Other research that finds a positive relationship between cooperation and amount spent on R&D includes Kaiser (2002b), Tether (2002) and Belderbos, Carree, Diederen, Lokshin and Veugelers (2004).

[185] By Dun and Bradstreet (2000).
[186] Though they are mainly concerned with whether this R&D spending is internalized by the UK.
[187] Other research with similar conclusion as to the role of appropriation and spillovers but more focused on the choice of partners used for cooperation includes Kaiser (2002b), Tether (2002), Boente and Keilbach (2005) and Tomlinson (2010).

‘Knowledge capital’ or technological competence is an asset that allows firms to maintain a competitive advantage. Griliches (1981) uses past R&D spending to capture this intangible capital. Endogenous growth models like the one by Aghion and Howitt (1992) lead to the conclusion that long-run growth rates are the result of R&D productivity which is interpreted as technological competence. Similarly Lee (2002) defines technology competence as firms R&D productivity and shows that this is closely related to R&D intensity. Many empirical studies of the determinants of innovation have thus measured technology competence and capability using R&D intensity (Bhattacharya and Bloch, 2004; Love and Roper, 1999; Lee, 2002; Lööf and Heshmati, 2006). R&D activities are and have been shown to be the most important known determinant of innovative outputs (CDM,1998; Freel, 2005; Vega-Jurado et al., 2008; Mairesse and Mohnen, 2010).

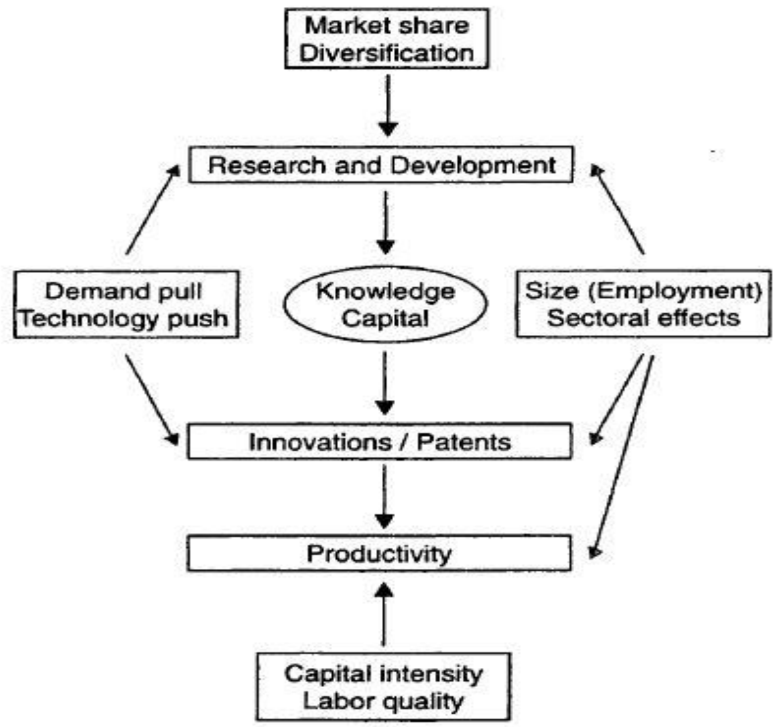
4.3. The CDM Approach

The methodological approach followed in this chapter is based on Crepon, Duguet and Mairesse (1998) work and has been used by many of the recent empirical investigations into the determinants of innovative activities at the firm level. The theoretical underpinnings for it are provided by the knowledge flow framework developed by Griliches (1979) and Griliches and Pakes (1984) (see figure 4.1 below). The derived structural model allows the researcher to estimate relations between innovation inputs and outputs as well as productivity taking account of both simultaneity and selection biases (Crepon, Duguet and Mairesse, 1998). More recent applications in this tradition are found in, for instance, Mairesse and Mohnen (2001), Lööf and Heshmati (2002), Griffith et al. (2006) and Mohnen, Mairesse and Dagenais (2006). Hall and Mairesse (2006) provide a review of studies in the CDM tradition.

Before turning to the details of the CDM model the issues of sample selection and simultaneity biases are briefly discussed. Sample selection occurs when the dependent variable can only be observed for a non-random sample of the population. In the CDM model this is the case for R&D spending which is only observed if it has a positive value and product innovation sales intensity which is only observed if the firm has introduced and started to sell a new product. The samples for which R&D spending or product innovation sales intensity are observed are non-random because the determinants of whether firms carry out R&D are similar to the determinants of how much they spend and likewise the determinants of introducing a product innovation are similar to the determinants of how much of a firm's sales consist of this product innovation. This means that the error term and the explanatory variables are correlated making least square estimates biased. This is because the covariance between the error term and the explanatory variables is not equal to zero, one of the main assumptions for carrying out OLS. The Heckman procedure is a means to overcome the sample selection problem. Details on how exactly this works are provided in the next section.

Simultaneity on the other hand means that certain variables are determined contemporaneously. This is relevant here because similar factors are found to drive R&D spending and innovative outputs. Likewise similar factors are thought to drive innovative outputs and productivity. As with sample selection, specifying a model in which the dependent variable and one of the explanatory variables are simultaneously determined causes the explanatory variable and the error terms to be correlated and thus OLS estimates are inconsistent and biased. To overcome this problem a reduced form model is estimated. This is done by solving for the endogenous variables which are in this case R&D spending, innovative outputs and productivity, which is the contribution of the CDM (1998) paper (equations 4.1 – 4.3 below). It is equivalent to an instrumental variable approach. The instrumental variables need to explain the endogenous variable while being uncorrelated with the dependent variable. Using all explanatory variables as well as the instrumental variables one obtains a prediction for the instrumented variables, in our case k, innovative inputs and t, the innovative output for equations 4.1 and 4.2. The predictions, $\hat{k}$ and $\hat{t}$, are uncorrelated with the error terms ε_2 and ε_3 (the error term for the model explaining productivity q) respectively and hence OLS regression provides asymptotically unbiased estimators. One therefore needs to have one or more variables that explain innovative inputs which do not explain innovative outputs and also one or more variables which explain innovative outputs that do not explain productivity. These variables are referred to as instruments or instrumental variables. Since the instruments coefficients in the model explaining the instrumented variable are restricted effectively to zero the choice of instruments is also referred to as identifying restrictions herein.

Figure 4.1, "Diagram of the model"; CDM (1998)



$$k = \beta_0^1 + \sum_m \beta_m^1 x_m^1 + \varepsilon^1 \tag{4.1}$$

$$t = \beta_0^2 + \beta_k k + \sum_l \beta_l^2 x_l^2 + \varepsilon^2 \tag{4.2}$$

$$q = \beta_0^3 + \beta_t t + \sum_j \beta_j^3 x_j^3 + \varepsilon^3 \tag{4.3}$$

The first relationship depicted in the knowledge framework by Griliches (1979) and Griliches and Pakes (1984) (equation 4.1) concerns which variables ($x_1, x_2, \ldots, x_m$) determine the amount of R&D spending, that is the knowledge production function (knowledge represented by k). This stage is estimated using a Heckman (1979) model. The advantage of this specification is that it provides a prediction of knowledge capital (k) for firms with zero R&D spending during the survey period.

The disadvantage is that it depends upon the rather strong assumption that the R&D production function takes the same functional form for firms with zero and positive R&D spending (Raffo, Lhuillery and Miotti, 2008). In the second stage (equation 4.2) estimated R&D spending (k), interpreted as knowledge capital (Griliches, 1979)[188], is used to explain innovative output (t). If the innovative outputs are measured as the share of sales of any product innovations introduced rather than the propensity to innovate, the researcher should again account for sample selection as, similar to R&D spending, the product sales intensity is only observed for those firms that have introduced a product innovation during the survey period. If on the other hand innovative outputs are measured as the introduction of product and/or process innovations equation 4.2 is estimated using a probit model. The last stage (equation 4.3) consists of a production function to show the effect of innovative outputs (t) on productivity (q). To overcome the potential simultaneity instrumented knowledge capital and predicted innovative outputs are used as explanatory variables in equations 4.2 and 4.3 respectively. The instruments for knowledge capital are explanatory variables included in equation 4.1 which are highly significant in explaining R&D intensity (k) but which are uncorrelated with innovative output (t). Likewise, the instruments for innovative output are explanatory variables highly significant in explaining innovative output (t) in equation 4.2 but which are uncorrelated with productivity (q). These are the identifying restrictions.

The exact implementation of the CDM methodology depends on the author's motives and data available to him. It is for instance used for cross country comparison of innovative activities such as in Griffith et al. (2006) and Mohnen, Mairesse and Dagenais (2006), a similar work by Raffo, Lhuillery and Miotti (2008) investigates the differences between developing and developed countries. Lööf and Heshmati (2006) conduct a sensitivity analysis of different error structures, different datasets, different measures of firms' performance and measures of innovative output. Roger's (2006) work aims to provide estimates of the rate of return to R&D. The CDM methodology has also been used to investigate the impact

[188] It should be noted that Griliches (1992) does point out that this is an imperfect measure as it neglects depreciation rate, lags in adding to R&D stock and the effect of spillovers.

of the European Framework Programme (Garcia, 2011). There are variations of the model as for instance found in Mohnen, Mairesse and Dagenais (2006), Roper, Du and Love (2008) and Doran and O'Leary (2011) which neglect the role of R&D, that is the first structural relationship in the CDM framework and instead just model the likehood of innovating straight away. Castellacci (2011) is the first to have included the Herfindahl concentration index in the CDM model and shows that firms in oligopolistic sectors have on average a higher likehood of carrying out innovative activities as well as spending more on R&D. As can be seen also from the list of specifications presented in the Appendix (4.8), variations exist in terms of the dependent and independent variables used, model stages included as well as whether identifying restrictions are used and if so which ones are chosen. As noted in the introduction this work specifically is aimed at confirming the contribution of the generated measures of absorptive capacity and appropriability. Since these are continuous measures it allows to investigate if these firm resources exhibit decreasing returns to scale, this is where the methodological contributions of this work lies.

The impact of the data available to the researcher on the exact model specification is discussed next. For instance only some studies have used product innovation sales intensity like the CDM paper rather than the introduction of product and process innovations as the innovative output measured in the second stage (Griffith et al., 2006; Raffo, Lhuillery and Miotti, 2008). CDM's work did not have information about process innovations[189] available and only had information on product innovations in terms of percentage bands of sales intensity[190] which thus forced them to rely on an ordered probit model for the estimation of the second structural relationship (equation 4.2). Other papers that have used innovative sales as the dependent variable for the second stage (equation 4.2) such as Janz, Lööf and Peters (2004) and Lööf and Heshmati (2006) accounted for the potential sample selection, that is only being included in the regression of equation 4.2 if one has positive innovative

[189] As argued in the literature review section (1.3) process innovations are an important innovative output in their own right often resulting in very direct benefits through cost reductions and quality increases. There are also product innovations that may have been considered process innovations due to the vertical integration of the firm. In other words there exists potential overlap among the two types of innovation which makes them difficult to distinguish.

[190] As well as information on patents introduced.

sales[191,192]. Using product innovation sales intensity as dependent variable in equation 4.2 and thus ignoring large parts of the population is somewhat forced onto researchers where parts of the information in the countries CIS is only available for innovative firms[193] and thus estimation of a probit model for process and/or process innovations would have meant discarding important information available from the dataset. A shortcoming these papers often already faced when estimating the first stage relationship (equation 4.1). As a result estimation of the third stage (equation 4.3), while accounting for sample selection, can also only be performed for innovative firms. Taking this route means that one needs to rely more strongly on the first stage of the model to correctly account for the sample selection since it is here where the error correction term included in the second and third stage are generated, none of the work surveyed has used a second sample selection model to generate these likely due to the increased number of assumptions about functional form required for such a specification. Lastly the product innovation sales intensity more than the introduction of a product innovation (or process innovation) is influenced by rates of diffusion. Rates of diffusion are determined by additional factors beyond those determining the introduction of a product or process innovation by a firm. These factors are also to a large extent demand side related ones which are not covered by the CIS implying that product innovation sales intensity besides the aforementioned issues is not an ideal choice as dependent variable for the second stage of the model (equation 4.2). What becomes clear from the discussion of the intricacies of the CDM model is that its application is strongly influenced by what data is available to the researcher.

Let's turn to some of the other limitations faced when making use of the CDM framework. Factors used to explain innovative activities relating to markets served,

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191 Though Castellacci (2011) for instance while estimating the innovative output equation for firms with innovative outputs only accounts for selection in the first stage (carrying out innovative activities) not in the second stage (carrying out innovative outputs). Similarly the original CDM ignores potential sample selection in the second stage.

192 Rather than accounting for sample selection twice, the sample selection model in the first stage (equation 4.1) is specified such that firms need to have carried out R&D and introduced a product innovation, the obtained error correction term (inverse mills ratio) is then included in the regression of stage 2 (equation 4.2).

193 Since only firms with innovative outputs are asked these questions, somewhat similar to what has been done in the CIS 6.

such as propensity to export and industry concentration but also the receipt of government support are very likely to have a two-way relationship with innovative outputs. Thus statistical inference may be invalid and lead to biased estimators. While the CDM methodology accounts for some of the complex, interrelated relationships that shape innovative activities it is doubtful that it can do full justice to the reality of the innovation process. A potential remedy for this is the use of instrumental variables which however would have to be orthogonal that is unrelated to the dependent variable according to theory. These are usually difficult to find and justify specifically given the limited knowledge about innovation process available to us requiring the researcher to make even further assumptions beyond the identifying restrictions already imposed. As noted the literature in the CDM tradition has to the author's knowledge[194] not instrumented variables beyond of course the first two dependent variables of the three stage simultaneous relationship, which are only in few cases explicated or justified. Nevertheless since all independent variables available from the CIS refer to the three year period of the survey these could be thought of as in part lagged variables and thus they are in some sense instrumented. Since the first dependent variable, R&D spending is based on information from the last year of the survey period. However the same is not true of the second dependent variable in the CDM framework, the sales of innovative outputs or product and process innovations introduced available from the CIS. he third dependent variable then again is based on the last year of the survey period while the explanatory varaibles could again be thought of as lagged.

Beyond the aforementioned issue the closely related lack of causality for models in the CDM tradition due to their reliance on cross sectional data sets is a major drawback (Crepon, Duguet and Mairesse, 1998; Fosfuri and Tribu, 2008), specifically because innovation and diffusion in particular are lengthy processes (Kafouros and Wang, 2008). This means with cross sectional data one cannot claim that the independent variables directly cause the dependent variables available to the researcher. Specifically it is problematic that innovative outputs are explained by information from the same time period in which they were generated and often thus based on activities that occur after the innovative outputs reported in the

[194] Apart from the work by Castellacci (2011) where industry concentration is instrumented.

survey period come about. This shortcoming is common to studies in this area because time series data is not available. There is however empirical evidence for the relative persistence of innovative activity over time[195] also confirmed to some degree in the data chapter (tables 2.23 and 2.24). Based on this observation the problem of a lack of causality between the dependent and independent variables available from cross sectional data may not be that grave. One could of course apply the use of panel data but this comes at the loss of the information on absorptive capacity and appropriation which are not available in the CIS 6 and which were a major reason for undertaking this work. Likewise the quality of the continuous data as discussed in the data chapter is plague by varying measurement errors which suggests that correlation in variability of R&D intensity and explanatory variables is likely to be spurious.

Another limitation to this study is the accuracy of the available R&D figures and what they represent. As Griliches (1992) notes R&D figures may reflect "incorrect" prices. That is externally purchased R&D may not reflect the "true" value of the R&D generated either due to too much or too little competition, in effect depending on appropriability conditions. Besides that as is shown in the data section the variations in the amount of R&D spending and thus R&D intensities from survey to survey are quite large opposed to what national figures suggest, which is that they remained fairly constant over time. It also needs to be kept in mind that the even if the product innovation sales intensity figure contained in the CIS was useful and could thus be used as dependent variable for stage 2, a true valuation of innovation outputs in terms of their social benefits cannot be achieved when looking only at the supply side. The question of the contribution to welfare of the innovative performance as explained in these models thus needs to be dealt with separately.

4.4. Methodology

The estimation procedure is now described in more detail, starting with the specification of the probit model and then turning to the Heckman model. The

[195] See Hall, Griliches and Hausman (1986) for R&D and patenting activity persistence.

probit model used to explain which firms innovate as well as in the first step of the Heckman model to explain which firms carry out R&D is specified as follows:

$$Z = \begin{cases} 1 & if \ Z^* > 0 \\ 0 & otherwise \end{cases} \tag{4.4}$$

Z indicates whether a firm carried out innovative activities or R&D for the 1st step of the Heckman model. Based on an underlying latent variable, Z^*, the latter is determined by a set of factors X':

$$\text{Where } Z^* = X'\gamma + \varepsilon \text{ where } \varepsilon \sim N(0,1) \tag{4.5}$$

To convert this into a model that can be estimated it is rewritten as the probability of carrying out the innovative activity ($Z = 1$) given the observed values for the factors X considered to influence this decision.

$$\Pr(Z = 1 | X) = \Phi(X'\gamma) \tag{4.6}$$

Here Φ represents the cumulative distribution function of the standard normal distribution. The parameters γ are then estimated using maximum likehood. The advantage of such a specification compared to simple OLS regression is that there are no heteroscedasticity[196] issues and that it allows for varying marginal effects of explanatory variables, that is a nonlinear relationship between explanatory variables and dependent variable. The latter is also important in order for the predicted values to be limited to a range from 0 to 1. The derivation of the above is based on the assumption that the error term ε is normal and thus:

$$\begin{aligned} &\Pr(Z = 1) = \Pr(Z^* > 0) \\ &= \Pr(X'\gamma > \varepsilon) \\ &= \Pr(\varepsilon > -X'\gamma) \\ &= 1 - \Pr(\varepsilon \leq -X'\gamma) \\ &= 1 - \Phi(-X'\gamma) \\ &= \Phi(X'\gamma) \end{aligned} \tag{4.7}$$

The Heckman specification is to explain the amount of R&D carried out by firms Y^*, X being a set of factors that determine this amount. Writing this as a linear model:

$$Y^* = X\beta + \upsilon \tag{4.8}$$

[196] Due to truncation affecting the size of the variance.

Since the amount of R&D spending is only observed for those firms that carry out R&D the unobserved error term υ is likely to be correlated with X. Use of OLS estimation would hence lead to biased results. To get a model that can be estimated the model is rewritten for those firms that carry out observable R&D. Based on the following assumption about the relative distribution of the error term in the initial linear model (υ) and the selection model (ε):

$$\begin{pmatrix} \upsilon \\ \varepsilon \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}\right) \tag{4.9}$$

the model estimated for those firms carrying out R&D then looks as follows:

$$E(Y \mid Z = 1) = X\beta + \rho \frac{\phi(X'\gamma)}{\Phi(X'\gamma)} + e \tag{4.10}$$

Where $\frac{\phi(z^j\gamma)}{\Phi(z^j\gamma)}$ is the inverse Mills ratio obtained from the first step probit specification estimating whether R&D is carried out or not and is included to correct for sample selection. ϕ represents the probability density function and Φ the cumulative probability density and ρ the coefficient of the inverse mills ratio. Using the assumption about the error terms distribution and the standard normalization restriction $\sigma_2^2 = 1$ the Heckman model can be derived as follows:

$$\begin{aligned} & E(Y \mid Z = 1) = X\beta + E(\upsilon \mid Z = 1) \\ & = X\beta + E(\upsilon \mid \varepsilon > -X'\gamma) \\ & = X\beta + \frac{\sigma_{12}}{\sigma_2^2} E(\varepsilon \mid \varepsilon > -X'\gamma) \\ & = X\beta + \sigma_{12} \frac{\phi(X'\gamma)}{\Phi(X'\gamma)} \\ & = X\beta + \rho \frac{\phi(X'\gamma)}{\Phi(X'\gamma)} \end{aligned} \tag{4.11}$$

Under the null hypothesis $H_0 : \rho = 0$ the statistical significance of ρ indicates whether there is a selection problem in the first place to account for because the coefficient of the inverse mills ratio measures the correlation between the error terms in the first step estimating the likehood of observing positive R&D expenditure as specified in equation 5.6 and the error term in equation 4.8. If it is significant then the standard errors should be adjusted since γ, the coefficient obtained from the probit model on which firms carry out R&D is estimated. The two steps in the Heckman model are estimated simultaneously which is termed "Full information maximum likehood" (FIML). The advantage of this approach is that ρ is chosen simultaneously, providing the researcher with the smallest possible variance for ρ and hence the most efficient estimators.

Since the Heckman model is estimated simultaneously the problem of identifying a unique solution may arise when both the selection and the outcome equation contain the same explanatory variables. That is because the same variation in the explanatory variables is used to explain selection and outcome. While, in theory, this should not be a problem because of the nonlinearity of the selection model[197], in practice, the nonlinearity may be insufficient for identification. Thus ideally one should include at least one variable in the first stage that is not present in the second stage and which has a substantial impact on the probability of selection. On theoretical grounds the variable used for identification should not play a role in determining R&D intensity but have a large impact on the likehood of carrying out R&D. The instruments used for identification at this stage are generally size or size-bands (see for example Janz, Lööf and Peters, 2004, Griffith et al., 2006 and Raffo, Lhuillery and Miotti, 2008).

Similarly the second stage innovation model as well as the third stage productivity model requires identification by instrumental variables. The identifying variables should have a strong correlation with the endogenous variable (that is instrumented k and t in equations 4.1 and 4.2) while not being correlated with the dependent variable. Unfortunately most of the papers in the CDM tradition neither explicitly state nor justify their choice of instruments (Lööf and Heshmati, 2006). In the original CDM specification (as laid out in the knowledge flow framework, figure 4.1) market share and diversification are used as instruments for identification of the second stage estimates and demand pull and technology push factors are used for identification of the third stage estimates. In a similar vein, Griffith et al. (2006) exclude an indicator of whether the firm's most important market was international[198] in the second stage of the model and likewise Janz, Lööf and Peters

[197] Thus for instance Crepon, Duguet and Mairesse (1998) and Castellacci (2011) use no identifying restrictions.
[198] As well as using the public support variable, however none of this is explicitly stated or rationalized.

(2004) exclude indicators of the location of firms' most important market. Griffith et al. (2006) drop the demand pull indicators as well as 'use of information sources' for the third stage model and similarly Janz, Lööf and Peters (2004) and Raffo, Lhuillery and Miotti (2008) drop variables measuring the use of information sources.

4.5. Data

The explained variable for the first structural relationship in the original CDM specification is R&D spending[199], while Griffith et al. (2006) use the reported intramural R&D spending as available from the CIS. This work due to the complementary nature of extramural and intramural R&D[200] uses the sum of these spending as the first dependent variable. A further reason why this approach is pursued is that increasingly firms outsource innovative activities to avoid being fully exposed to the risk these involve (Soete and Freeman, 2009). Thus more and more firms can be expected to have their R&D activities reported as extramural rather than intramural activities. The R&D spending is as convention in the literature divided by the number of employees and logarithmically transformed. As a result the coefficients are to be interpreted as semi-elasticities or full elasticities if the right hand side variables are logarithmically transformed as well. The predicted logarithmic R&D spending per employee from the first stage of the model is in the next stage in accordance with the knowledge flow framework by Griliches and Pakes (1984) interpreted as a proxy for knowledge capital of the firm. The dependent variable in the second stage model is whether firms have introduced innovations (either product or process). Similar models can be estimated where the dependent variable is whether firms have introduced innovations in the form of goods or in the form of services as well as whether they introduced product or process innovations. The dependent variable in the third stage, firm level productivity is proxied by total sales divided by the number of employees logarithmically transformed[201].

199 As collected by the "Ministere de la Recherche", France, using an "annual firm research expenditure survey".
200 Pisano (1990), Veugelers (1997), Cassiman and Veugelers (2006) and Lopez (2008) provide evidence for the complementary use of R&D sources.
201 Lööf and Heshmati (2006) provide evidence for the validity of proxying productivity with total sales per worker.

It is now shortly explained why in this work the dependent variable is chosen to be the introduction of innovations rather than using product sales intensity figures as in some papers following the CDM approach[202]. The product sales intensity figure as has been argued in the data chapter does not reflect the percentage sales form the point of introducing the product innovation but instead the sales figure for the last year of the survey period for product innovations introduced at any point of the three years the survey period covers. To put it differently very little of the information content within this figure can be attributed to be the result of differing innovative performance of firms. Mostly it is influenced by the nonlinear time trend of diffusion[203] combined with the effect of the (random) timing of the introduction of the product innovation. The timing also impacts this figure by censoring sales which may have occurred in the first two years of the survey period. Based on the information contained in the CIS it is impossible to disentangle these effects from the factors actually determining the innovative output of a firm. Finally and most importantly using product sales intensity as dependent variable would limit the second stage to be estimable only for those firms with positive product innovation sales and requires one to account for potential sample selection as these firms are not a random sample. It was felt that this means a large loss of information in terms of observations as well as ignoring process innovations which by other firms may have been reported as product innovations, if their vertical area of activity is narrower. That is the two are difficult to distinguish in the first place. For these reasons the second stage dependent variable is the introduction of both product and process innovations allowing this model to be estimated for all observations.

[202] From those which were reviewed, Janz, Lööf and Peters (2004) and Lööf and Heshmati (2006).
[203] The speed of diffusion is characterized by an S-shape (Metcalfe, 2004).

Table 4.1, List of variables used

exogenous variables	dataset	Heckman step 1	Heckman step 2	Stage 2	Stage 3	expected sign	note
log(employment)	IDBR	X		X	X	positive	number of employees in the enterprise
“industries”	IDBR	X	X	X	X	varying	industry dummies (division)
Absorptive capacity	CIS	X	X	X		inverted U type	factor based on sources of information for innovation
Appropriation	CIS	X	X			inverted U type	factor based on importance of methods of appropriation
Market share	ARD	X	X			positive	enterprise market share (for 2 digit 92 SIC)
log(Herfindahl)	ARD	X	X			U type / positive	industry concentration index (based on 2 digit 92 SIC)
Foreign ownership	IDBR	X	X			varying	enterprise belongs to foreign firm
Exporter	CIS	(X)	(X)			positive	enterprise sells to foreign markets
Public support	CIS	(X)	(X)				received public financial support for innovation
"regions"	IDBR	X	X	X	X		enterprise is located in England/Wales/Scotland
Physical capital/employee	CIS				X	positive	spending on machinery, equipment and software / # of employees
% science degree	CIS				X	positive	% of employees that has a science degree
% other degrees	CIS				X	positive	% of employees that has a non-science degree
endogenous variables							
R&D performers	CIS						firms with positive R&D spending (intra and extramural)
log (R&D spending/ employee)	CIS						R&D spending (intramural and extramural, per employee)
Innovator	CIS						introduced a product or process innovation
log (productivity)	ARD						total sales / number of employees
instrumented variables							
Predicted log (R&D spending)				X			instrumented R&D spending for all firms
Predicted innovator					X		instrumented propensity to innovate

Crepon et al. (1998) capture “demand pull and technology push” by a two part question contained in the 1990 French Innovation Survey carried out by the SESSI (Service des Statistiques Industrielles). It reads “Do you consider that in your firm innovation is determined” 1. “through the impetus given by the market (relationships with customers, competitors)?” and 2. “by technology specific dynamics” assessed on a four point scale. This information was only collected for firms that were innovatively active[204]. In contrast Griffith et al. (2006) measure demand pull by indicators that reflect whether ‘regulations and standards’ and ‘environmental and safety aspects’ were important to innovation[205]. They as well as Raffo, Lhuillery and Miotti (2008) use the question set contained in the CIS about information sources used by the firms for their innovative activities[206] to explain R&D spending in the 1st stage model[207]. Like Janz, Lööf and Peters (2004) and Lööf and Heshmati (2006) the former two papers also used this information in the second stage of the model, that is it was believed to be a determinant of innovative outputs. The equivalent question set for the UK CIS is the one which has been used to derive the ‘absorptive capacity’ measure[208]. However the notable difference here is that for the UK CIS this information is available for all firms in the CIS 4 and the CIS 5 and not just those that have innovative outputs. While for the CIS 6 this no longer is the case thus no measure of absorptive capacity could be created for the whole sample and this as noted is one reason why the CIS 6 is not included in this analysis. Ignoring this information for firms that are not considered “innovation active” would have meant that this variable is likely to become (more) endogenous. It would also mean that one assumes that firms with no innovative activity during

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[204] Defined as “those that answered ‘yes’ to at least one of the following eight questions: did you perform in the five last years (…) and innovation of the following type: (i) product improvement; (ii) new product for the market; (iii) product imitation (i.e. new for the firm but not for the market); (iv) technological breakthrough; (v) process improvement; (vi) packaging innovation (explicitly excluded from i, ii and iii in the questionnaire); (vii) organizational innovation linked to the introduction of technological change (viii) marketing innovation. About 60% of the French manufacturing firms have innovated according to this definition…”.

[205] These questions in the CIS 5 were only posed to firms that introduced product and process innovations and in the CIS 6 only to those deemed “innovation active”. It is thus due censoring likely to be endogenous and has thus not been included as an explanatory variable.

[206] This includes inputs from ‘firm internal sources’, ‘universities’, ‘governments’, ‘suppliers’, ‘competitors’ and ‘customers’.

[207] Both only use it for the second and not the first step of the R&D model. This is because this information is only available for innovation active firms for (most of) the countries included in their analysis.

[208] A distinction into ‘technology push’ and ‘demand pull’ could also be identified when the two factor solution on sources of information was obtained in the previous chapter. One factor was centred on scientific knowledge and the other around market knowledge.

the survey period do not possess absorptive capacity, or indeed have average absorptive capacity as the measure generated is centred on zero, which is also not true as they are more likely to have below average absorptive capacity[209]. Lhuillery (2011) using the first stage of the CDM framework to analyse Swiss innovation data interprets 'the importance of sources of information for innovation' as measures of absorptive capacity and shows that its effects are overestimated if only included for those firms that have innovative outputs. In fact he finds that knowledge from rivals can deter R&D activities and thus there may be decreasing returns to absorptive capacity. For this reason its measure is also included as a squared term in the model.

Appropriation has been shown to be important in determining innovation as such and thus has also been included as explanatory variable in the CDM literature. For instance Griffith et al. (2006) use information on whether firms have used formal and strategic protection[210] showing it to be significant in explaining R&D spending and participation while Lööf and Heshmati (2006) just include this information to explain R&D propensity. From the evolutionary perspective and the resource based perspective firms are highly heterogeneous in terms of their knowledge stock, their activities and likewise in terms of the market they serve. The appropriability of returns is thus firm specific. The responses to the question about the importance of appropriation methods for firm's innovations should thus capture the appropriability of their knowledge in the markets they operate in and is thus expected to be an important determinant of innovative activities. Teece (1986) argues that too much protection may have negative effects on innovative activities as it detracts resources from potentially beneficial cooperation and Dosi, Marengo and Pasquali (2006) in their review of the theoretical and empirical literature confirm this. For this reason a squared term of the appropriation measure has been included as well in the regression to account for a potential inverted U-type relationship. That the information about rating of appropriation methods is not

[209] Though this could have been accounted for by a dummy, this would throw these possibly differing firms into the same pot.

[210] They have also though used this information as explanatory variable in the second stage, however these variables were not significant (except for process innovation, where formal protection had a negative impact) for the UK CIS.

available in the CIS 6 is the other reason why this dataset has not been included in the analysis.

The choice of the other explanatory variables included here is on the one hand guided by what has been discussed are the determinants of innovative activities (section 4.2) and on the other hand by what information is available from the UK CIS and the ARD. For instance CDM (1998) measure market share as well as diversification based on the information of sales by each firm into 227 manufacturing industry segments. This sort of information is not available from the CIS though, it is probably for this reason that other literature in the CDM tradition relying on the CIS has not included market share and diversification as explanatory variables. Market share information however can be obtained from the ARD, for all firms except for those in Northern Ireland. Hence this work has relied on information from the ARD to compute the market share as well as industry (Herfindahl) concentration[211] based on 2 digit SIC 92 code industries. This was at the expense of dropping the Northern Irish respondents to the CIS. However using the information in the ARD no measure of diversification can be computed[212]. The other dependent variables included which are standard in the literature are logarithmically transformed employment size and industry sector dummies as well as a cooperation dummy in the second step of the Heckman model as featured for instance in the models of Janz, Lööf and Peters (2004), Griffith et al. (2006), Raffo, Lhuillery and Miotti (2008). Regional dummies for Scotland and Wales have been included, regional dummies have generally not been included in CDM type models but it was felt these regional dummies could potentially reflect different systemic environments thought to be important in determining innovative behaviour. The rational is that these regions have certain autonomy in their policy making and are to some extent geographically remote[213], both of which are thought to reflect natural barriers to innovation systems. A dummy representing foreign ownership has

[211] Industry concentration as discussed in the literature review section is thought to impact innovative activities and Castellacci (2011) shows that it is statistically highly significant. It is computed as the sum of the squared market shares of each firm part of an industry division.
[212] Since a single industrial classification is applied for each reporting unit / firm depending on what the main activity of the firm was judged to constitute.
[213] The inclusion of these regional dummies can thus also be motivated based on the core periphery hypothesis presented in section 5.2.

been included since as discussed in the literature review foreign owned firms potentially carry out their main R&D activities in their home country. Lastly export propensity is added (included for example by Griffith et al., 2006; Raffo, Lhuillery and Miotti, 2008) tentatively as it is not clear which way the causality with innovative activities runs. In the last stage explaining productivity following the CDM methodology 'capital intensity' proxied by spending on machinery, equipment and software per employee in the last year of the survey period as well as 'labour quality' using information about the percentage of staff employed that hold a science degree or any other degree are included. The choice of dependent variables is summarized in table 4.1.

For identification of the first stage of the model, that is the model explaining R&D intensity (R&D spending per employee) size is included as explanatory variable in the first step of the Heckman and not in the second step, this is the standard approach followed for instance in Janz, Lööf and Peters (2004), Griffith et al. (2006), Raffo, Lhuillery and Miotti (2008). This is justified based on the argument that while size has a positive impact on innovative activities this correlation is likely to be weaker once R&D spending has been scaled for size. As in the CDM specification market related factors (in their case market share and in the case of others work export propensity[214]) are used as instrumental variables for R&D intensity in the innovative output equation. These market related factors are for this work assumed to be market share, the Herfindahl index, foreign ownership as well as importance of appropriation measures[215] which as argued is related to the firm specific market. The exclusion of the appropriation measure is also rationalised on the basis that having sufficient knowledge capital to generate an innovation it would seem that the appropriability of such an innovation should not have an impact on whether it is introduced or not. It is thus assumed here that appropriation does not influence the likehood of innovating. For the third stage as per knowledge flow framework by Griliches and Pakes (1984) followed in the original CDM specification the demand pull and technology push components are dropped for identification. These are most similar to the generated absorptive

[214] Janz, Lööf and Peters (2004) and Griffith et al. (2006).

[215] This is also in line with Lööf and Heshmati's (2006) approach as well as the finding by Griffith et al. (2006) that appropriation is not significant in their second stage model.

capacity measure and it has thus been used as instrument for the second stage dependent variable. Likewise Griffith et al. (2006) and Raffo, Lhuillery and Miotti (2008) exclude the 'sources of information used for innovation' variables for identification of this stage.

Table 4.2, Weighted % of R&D performers by sizeband and N

	Percentages			Sample sizes		
	CIS 4	CIS 5	CIS6	CIS 4	CIS 5	CIS6
Year	2004	2006	2008	2004	2006	2008
9-19	18.6	19.8	20.2	4937	4135	3452
20-49	23.1	22.2	26.3	3485	2983	2438
50-99	29.2	28.0	32.2	2351	1898	1972
100-199	33.5	35.2	33.9	1084	948	978
200-499	35.7	35.3	36.5	1934	1782	1636
500+	36.6	38.1	36.3	1566	1352	1199
Total	22.6	22.8	24.6	15357	13098	11675

For the distribution of R&D performers[216] by sizeband (table 4.2), in line with the findings of the empirical literature presented in the review section a substantially higher percentage of larger firms spend on R&D. This on the one hand is explained by the formalization of R&D activities in larger firms and on the other by their financial prowess meaning they are more able to spread risks and obtain funding for such undertakings. However no causality can be claimed from these tables without controlling for other effects first. Next we turn to the breakdown of R&D performers by industry (table 4.3). The percentage of R&D performers by industry shows large variations potentially reflecting varying technological opportunities. From these figures no clear distinction can be drawn among manufacturing and services (all industries starting from wholesale trade). The most important sectors in terms of R&D spending include the 'manufacturing of electrical and optical equipment' where over half of the firms carry out R&D. Very similar in terms of percentage of R&D performers are 'computer and related activities'. Some industries exhibit quite a bit of volatility in terms of the proportion of firms that report spending on R&D from survey to survey including 'mining and quarrying', 'electricity gas and water', 'post and courier activities', 'telecommunications' and 'technical testing and analysis'. Some of these differences are likely due to the

[216] Those reporting positive R&D spending in the last year of the survey period.

relatively small sample size that these averages were based on as well as changes in the number of respondents.

Table 4.3, Weighted % of R&D performers by industry and N

	Percentages			Sample Sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Year	2004	2006	2008	2004	2006	2008
Mining and quarrying	28.0	13.2	22.0	149	47	88
Mfr of food, clothing, wood, paper, publish & print	29.2	30.8	37.6	1391	1325	906
Mfr of fuels, chemicals, plastic metals & minerals	35.0	37.0	40.5	1835	1958	1069
Mfr of electrical and optical equipments	53.0	60.4	60.5	649	448	505
Mfr of transport equipments	41.5	46.9	42.4	382	236	324
Mfr not elsewhere classified (including electricity, gas & water)	41.5	39.0	42.1	498	338	374
Construction	10.6	11.4	12.9	1530	923	934
Wholesale trade (incl cars & bikes)	20.7	20.2	21.4	1290	1162	1035
Retail trade (excl cars & bikes)	11.8	14.8	14.4	1484	852	801
Hotels & restaurants	10.5	9.3	11.3	929	782	757
Transport, storage	14.8	12.8	16.5	1014	990	901
Post & Courier activities	16.3	21.2	4.9	136	71	132
Telecommunications	41.3	18.4	38.6	105	52	72
Financial intermediation	32.1	29.6	32.3	631	422	429
Real estate	14.9	11.2	15.1	385	528	590
Renting of Machinery and Equipment	13.9	12.7	16.9	259	242	337
Computer and Related Activities	57.1	57.8	56.8	424	472	417
Architectural and engineering activities	39.3	35.9	36.1	411	468	477
Technical testing and analysis	31.0	43.9	42.9	106	44	99
Other business activities	19.1	19.9	22.6	1749	1738	1428
Total	22.6	22.8	24.6	15357	13098	11675

Table 4.4, Weighted % of R&D performers by region and N

	Percentages			Sample Sizes		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Year	2004	2006	2008	2004	2006	2008
England	23.2	23.7	25.3	11782	10012	8823
Wales	20.8	20.4	21.4	1055	1034	877
Scotland	20.2	18.2	23.6	1185	1091	999
Northern Ireland	16.3	15.2	17.8	1335	961	976
Total	22.6	22.8	24.6	15357	13098	11675

The distribution of R&D performers by regions (table 4.4) shows that the largest proportion of R&D performers can be found in England. Northern Ireland has the smallest proportion of R&D performers with Wales and Scotland faring somewhere in between and figures for the later but also for Northern Ireland showing some fluctuations across the surveys.

Table 4.5, Weighted R&D spending / employee if > 0, by sizeband and N

	Spending			Observations		
	CIS 4	CIS 5	CIS6	CIS 4	CIS 5	CIS 6
Year	2004	2006	2008	2004	2006	2008
9-19	3944	2694	2977	955	874	773
20-49	3318	2150	1993	900	780	731
50-99	2044	2237	2679	746	521	626
100-199	2165	2155	1841	386	328	341
200-499	1827	1905	2224	737	611	557
500+	2439	2489	2318	580	502	425
Total	3237	2390	2480	4304	3616	3453

Table 4.6, Weighted R&D spending / employee if > 0, by industry and N

	Spending			Observations		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Year	2004	2006	2008	2004	2006	2008
Mining and quarrying	3605	2691	2637	56	13	25
Mfr of food, clothing, wood, paper, publish & print	1033	1062	1870	519	496	385
Mfr of fuels, chemicals, plastic metals & minerals	1919	1762	1612	749	762	480
Mfr of electrical and optical equipments	4073	4277	6031	363	274	318
Mfr of transport equipments	1995	2098	3046	178	117	138
Mfr not elsewhere classified (including electricity, gas & water)	2063	1053	1052	207	138	168
Construction	1587	506	835	203	130	155
Wholesale trade (incl cars & bikes)	1852	2131	2007	274	238	227
Retail trade (excl cars & bikes)	1437	1107	1251	193	142	122
Hotels & restaurants	1621	297	502	134	100	120
Transport, storage	975	714	675	166	132	154
Post & Courier activities	1961	526	1483	26	16	15
Telecommunications	6351	4718	13298	67	18	39
Financial intermediation	3959	1517	1549	203	125	148
Real estate	2873	752	1637	72	73	104
Renting of Machinery and Equipment	1138	3129	3082	61	39	57
Computer and Related Activities	11207	8164	6436	252	270	244
Architectural and engineering activities	4353	2200	3368	178	173	193
Technical testing and analysis	1394	1051	1848	51	16	44
Other business activities	2709	1473	2240	352	344	317
Total	3237	2390	2480	4304	3616	3453

Table 4.7, Weighted R&D spending / employee if > 0 , by region and N

	Spending			Observations		
	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Year	2004	2006	2008	2004	2006	2008
England	3206	2486	2514	3370	2867	2662
Wales	2572	1971	1778	308	284	246
Scotland	2880	1537	2480	321	272	299
Northern Ireland	5755	1753	2344	305	193	246
Total	3237	2390	2480	4304	3616	3453

Let's turn to the amount of R&D spent per employee for those firms performing R&D. The R&D intensity varies across size (table 4.5), a slightly U shaped relationship can be identified. Distribution of R&D intensities across industries shows large variations (table 4.6). The largest R&D spenders are found in the 'manufacturers of electrical and optical equipments' as well as in 'computers and related activities' divisions. Again no clear distinction can be drawn between service and manufacturing sectors based on the spending intensities, fluctuations across industry sectors are much more pronounced. Region wise (table 4.7) fluctuations in reported R&D intensities across survey rounds are also large. The most notable here is the relatively high spending by Northern Ireland for the CIS 4. Overall though it appears that in the non-English regions R&D performers spend less on R&D. The R&D intensity figures in general are at a considerably higher level for the CIS 4 compared with the CIS 5 and the CIS 6.

Table 4.8, Weighted % of innovators by industry and N

	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
Mining and quarrying	0.24	0.19	0.26	152	53	94
Mfr of food, clothing, wood, paper, publish & print	0.36	0.38	0.37	1437	1434	1091
Mfr of fuels, chemicals, plastic metals & minerals	0.41	0.39	0.37	1904	2116	1278
Mfr of electrical and optical equipments	0.60	0.54	0.52	666	491	583
Mfr of transport equipments	0.42	0.38	0.34	399	260	383
Mfr not elsewhere classified (including electricity, gas & water)	0.44	0.38	0.40	515	363	434
Construction	0.14	0.13	0.16	1613	1028	1059
Wholesale trade (incl cars & bikes)	0.29	0.23	0.26	1342	1325	1216
Retail trade (excl cars & bikes)	0.19	0.21	0.22	1547	936	946
Hotels & restaurants	0.13	0.18	0.21	991	877	908
Transport, storage	0.22	0.20	0.19	1058	1120	1050
Post & Courier activities	0.31	0.34	0.28	139	77	146
Telecommunications	0.50	0.37	0.47	111	60	85
Financial intermediation	0.39	0.30	0.30	673	503	536
Real estate	0.21	0.18	0.17	416	618	747
Renting of Machinery and Equipment	0.26	0.20	0.21	272	272	388
Computer and Related Activities	0.69	0.56	0.54	439	517	477
Architectural and engineering activities	0.41	0.33	0.37	423	522	572
Technical testing and analysis	0.53	0.40	0.47	110	49	118
Other business activities	0.32	0.24	0.28	1801	1974	1745
Total	0.29	0.26	0.28	16008	14595	13856

Table 4.9, Weighted % of innovators by sizeband and N

	CIS 4	CIS 5	CIS6	CIS 4	CIS 5	CIS6
9-19	0.25	0.25	0.26	5224	4711	3994
20-49	0.29	0.26	0.27	3628	3291	2788
50-99	0.36	0.30	0.32	2423	2080	2250
100-199	0.40	0.32	0.34	1121	1034	1139
200-499	0.45	0.35	0.32	1989	1945	2062
500+	0.48	0.37	0.36	1623	1534	1623
Total	0.29	0.26	0.28	16008	14595	13856

Table 4.10, Weighted % of innovators region and N

	CIS 4	CIS 5	CIS 6	CIS 4	CIS 5	CIS 6
England	0.30	0.27	0.28	12339	11189	10734
Wales	0.27	0.25	0.27	1090	1128	968
Scotland	0.25	0.23	0.26	1236	1204	1154
Northern Ireland	0.29	0.24	0.21	1343	1074	1000
Total	0.29	0.26	0.28	16008	14595	13856

The proportion of firms that report to have innovated increases with firm size (table 4.9). In terms of the proportion of innovators found in various industries (table 4.8) the ‘manufacturing of electrical and optical equipments’ and ‘computer and related activities’ are the most innovative, though the other industries do not lag much behind. As for the distribution of R&D performers and amount of R&D spending the manufacturing and service industries cannot be clearly distinguished from one another. The percentage of firms that have introduced innovations is very similar across the different regions (table 4.10). Like for the proportions reporting R&D spending the averages vary somewhat from survey to survey. However these fluctuations (unlike for the information about R&D performers) are also observed in industries which contain a large number of observations in the sample. Notably a larger percentage of firms innovate then the proportion that carries out R&D. Partly this is going to be due to the figures on whether firms performed R&D referring only to the last year of the survey, whereas the figures about whether firms innovated to the whole three years covered by the survey. To some extent this is also likely a result of firms having informal innovative activities. Both points provide grounds for the use of predicted R&D spending as a measure of knowledge capital.

4.6. Results

Table 4.11, Weighted means of the variables

	CIS4	CIS5
N	13836	11438
R&D performers	0.233	0.242
log R&D intensity (for R&D performers)	6.394	6.270
Innovators	0.309	0.305
Novel product or process	0.159	0.143
Product innovation	0.261	0.270
Process innovation	0.158	0.133
Goods innovation	0.161	0.169
Service innovation	0.172	0.206
Novel product innovation	0.146	0.134
Novel process innovation	0.046	0.034
Public support	0.077	0.000
Log (Herfindahl)	-5.417	-5.467
Market share	0.000	0.000
Foreign ownership	0.054	0.067
Exporter	0.264	0.301
Absorptive capacity	0.008	0.010
Absorptive capacity^2	0.738	0.724
Appropriation	0.009	0.013
Appropriation^2	0.630	0.774
England	0.879	0.877
Wales	0.041	0.041
Scotland	0.080	0.082
Ireland	0.000	0.000
log(employment)	3.286	3.277
Mining and quarrying	0.001	0.001
Mfr of food, clothing, wood, paper, publish & print	0.066	0.067
Mfr of fuels, chemicals, plastic metals & minerals	0.098	0.102
Mfr of electrical and optical equipments	0.024	0.023
Mfr of transport equipments	0.009	0.009
Mfr not elsewhere classified	0.017	0.017
Electricity, gas & water supply	0.000	0.000
Construction	0.102	0.102
Wholesale trade (incl cars & bikes)	0.145	0.144
Retail trade (excl cars & bikes)	0.084	0.084
Hotels & restaurants	0.127	0.126
Transport, storage	0.052	0.052
Post & Courier activities	0.004	0.004
Telecommunications	0.002	0.002
Financial intermediation	0.024	0.023
Real estate	0.046	0.043
Renting of Machinery and Equipment	0.020	0.019
Computer and Related Activities	0.046	0.048
Architectural and engineering activities	0.042	0.042
Technical testing and analysis	0.002	0.002
Other business activities	0.090	0.087

Table 4.12, Heckman step 1 R&D participation (0/1)

Sample	CIS4	CIS 4	CSI 4	CIS 5	CIS 5	CIS 5
Observations	13929	13929	13848	11487	11487	11458
log(employment)	0.148***	0.139***	0.135***	0.098***	0.098***	0.087***
	(0.013)	(0.012)	(0.013)	(0.026)	(0.026)	(0.028)
Wales	0.016	0.014	0.028	-0.128*	-0.128*	-0.115*
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
Scotland	-0.034	-0.034	-0.031	-0.161**	-0.160**	-0.163**
	(0.071)	(0.071)	(0.072)	(0.077)	(0.077)	(0.077)
Foreign ownership	-0.191***	-0.200***	-0.285***	-0.036	-0.036	-0.048
	(0.067)	(0.066)	(0.067)	(0.088)	(0.088)	(0.089)
log(Herfindahl)	0.064**	0.055*	0.044	0.080***	0.080***	0.060**
	(0.031)	(0.030)	(0.030)	(0.029)	(0.029)	(0.029)
Market share	-18.971***			0.197		
	(4.562)			(4.986)		
Absorptive capacity	0.768***	0.768***	0.761***	0.756***	0.756***	0.753***
	(0.034)	(0.034)	(0.034)	(0.039)	(0.039)	(0.040)
Absorptive capacity^2	-0.336***	-0.336***	-0.333***	-0.238***	-0.238***	-0.232***
	(0.026)	(0.026)	(0.026)	(0.028)	(0.028)	(0.028)
Appropriation	0.711***	0.711***	0.669***	0.512***	0.512***	0.470***
	(0.044)	(0.044)	(0.045)	(0.048)	(0.048)	(0.049)
Appropriation^2	-0.222***	-0.222***	-0.214***	-0.146***	-0.146***	-0.140***
	(0.024)	(0.024)	(0.024)	(0.025)	(0.025)	(0.025)
Exporter			0.290***			0.301***
			(0.044)			(0.049)
p - Wald joint sig. divisions	0.000	0.000	0.000	0.000	0.000	0.000

Tables 4.12 and 4.13 present the results of the Heckman model. The parameters are marginal effects computed at their sample mean, for the dummy variables these are the effects when they change from 0 to 1. The results confirm the importance of the firm size, industry membership, industry concentration, absorptive capacity, appropriation and if included export propensity as well as the receipt of public support[218] in explaining reported R&D activities. However they reject that either market share, foreign ownership or regional membership has a consistent or significant effect.

[218] The specification with public support included (table 5.12 and 5.13, pages 283 and 284) is only presented in the next chapter though to confirm that it is endogenous.

Table 4.13, Heckman step 2 - log (R&D spending/employment)

Sample	CIS4	CIS 4	CSI 4	CIS 5	CIS 5	CIS 5
Observations	3936	3936	3932	3369	3369	3362
Cooperation	0.254***	0.256***	0.239***	0.248***	0.248***	0.232***
	(0.084)	(0.084)	(0.084)	(0.081)	(0.081)	(0.080)
Wales	0.007	0.007	0.040	-0.075	-0.074	-0.016
	(0.135)	(0.135)	(0.134)	(0.144)	(0.144)	(0.144)
Scotland	-0.081	-0.082	-0.075	-0.176	-0.175	-0.192
	(0.156)	(0.156)	(0.155)	(0.138)	(0.138)	(0.137)
Foreign Ownership	-0.103	-0.109	-0.308**	0.091	0.092	0.060
	(0.137)	(0.135)	(0.137)	(0.146)	(0.146)	(0.143)
log(Herfindahl)	0.161***	0.155***	0.133**	0.165***	0.166***	0.134**
	(0.060)	(0.060)	(0.059)	(0.056)	(0.055)	(0.053)
Market share	-5.423			3.202		
	(10.369)			(7.880)		
Absorptive capacity	1.009***	1.001***	0.972***	0.751***	0.750***	0.683***
	(0.155)	(0.156)	(0.154)	(0.225)	(0.224)	(0.228)
Absorptive capacity^2	-0.454***	-0.451***	-0.429***	-0.297***	-0.297***	-0.262***
	(0.085)	(0.085)	(0.083)	(0.095)	(0.094)	(0.094)
Appropriation	1.689***	1.684***	1.564***	1.042***	1.042***	0.930***
	(0.111)	(0.112)	(0.112)	(0.143)	(0.142)	(0.140)
Appropriation^2	-0.453***	-0.452***	-0.431***	-0.252***	-0.252***	-0.231***
	(0.054)	(0.054)	(0.054)	(0.055)	(0.055)	(0.054)
Exporter			0.743***			0.561***
			(0.096)			(0.105)
p - Wald joint sig. ind.	0.000	0.000	0.000	0.000	0.000	0.000
p - Wald sig. - rho	0.000	0.000	0.000	0.000	0.000	0.000
p - Wald indep. equa.	0.000	0.000	0.000	0.000	0.000	0.000
Log-likehood	-127525.0	-127570.9	-126615.3	-117155.8	-117156.2	-116216.1

The controls for regions different systemic background show that firms in Scotland are generally less likely to carry out R&D, this effect being only significant for the CIS 5. For Wales the coefficients are positive for the CIS 4 and negative for the CIS 5, in the latter case they are significant. The impact of regional membership on the amount of R&D spending is again negative for Scotland. These effects are never significant though. For Wales the effects are positive for the CIS 4 and negative for the CIS 5 with these not being significant in either case.

The variable representing firm size has as expected a positive coefficient in explaining the likehood of carrying out R&D which is significant at all times. The size coefficients are somewhat smaller for the CIS 5 then the CIS 4. The observation of a positive relationship of size and R&D propensity is in line with Schumpeterian thinking where larger size confers an advantage in carrying out R&D but also in line with the observation that small firms have less formalized R&D activities as well as the findings of the previous literature in the CDM tradition (Crepon, Duguet and Mairess, 1998; Griffith et al., 2006; Lööf and Heshmati, 2006; Raffo, Lhuillery and Miotti, 2008; Janz, Lööf and Peters, 2004; Catellaci, 2011; Lhuillery, 2011).

The appropriation index has as expected a positive and significant effect on the likehood and amount of R&D carried out. This is in agreement with the findings of Griffith et al. (2006) and Lhuillery (2011). The negative sign on its square indicates that the stimulating effect of appropriability conditions occur at a decreasing rate and thus corroborates that there is an optimum level of appropriation for stimulating innovative activities (Dosi, Marengo and Pasquali, 2006). A result that has not been previously shown using the CDM methodology and which is a direct advantage of creating an appropriation measure using factor analysis rather than relying on simply dummy variables as in the two aforementioned works.

The absorptive capacity measure has a positive and statistically significant impact on the probability to carry out R&D and the amount of R&D spending. This confirms the importance of this intangible resource in driving R&D activities as pointed out by Cohen and Levinthal (1990). Since this measure was created based on the question about the 'use of sources of information for innovation' it is also in line with the results of Griffith et al. (2006) and Raffo, Lhuillery and Miotti (2008) who find a positive effect of these on the amount of R&D spending. Like for appropriation the squared absorptive capacity measure has a negative and significant coefficient and also here it represents a new finding in the literature which is made possible through the use of a continuous measure of absorptive capacity. This sort of finding is plausible given that the more absorptive capacity a firm has the less additional learning it needs to carry out in order to exploit external knowledge.

When the factor analysis to generate the aforementioned measures was conducted based on simply dummies rather than using the Likert scale they are assessed on, the same inverted U-type relationships could be identified. These can thus not be attributed to subjective scaling by respondents. That is some firms judging the effects or information sources having little and others large importance when indeed they had simply made use of them and formed an inaccurate subjective opinion about them. These findings confirm the usefulness of capturing more of the information content provided in the CIS as done here using factor analysis.

The foreign ownership variable has a negative coefficient in estimating the probability to carry out R&D which is only significant for the CIS 4 dataset though. The coefficient of foreign ownership for the equation estimating the amount of R&D spending is negative for the CIS 4 and significant only if an explanatory variable for exporters is included. For the CIS 5 its coefficient in explaining the amount of R&D spending is positive but not statistically significant.

The log Herfindahl index has positive coefficients for the regressions explaining the likehood of carrying out R&D as well as those that explain the amount spent on R&D, these coefficients are most of the time highly significant. This observation is in line with the findings of previous research (Scherer, 1965; Levin, Cohen and Mowery, 1985; Castellacci, 2011). It indicates that in industries that are more concentrated, that is there exist a few firms only with large market shares, firms carry out R&D activities more often and spend more on R&D. However the only use of industry concentration as explanatory variable within the CDM framework is found in Castellacci (2011) where it was calculated by extrapolation of the CIS data using the included weights. Instead here actual population data was used from the ARD to generate this variable and thus this measure should be more accurate. Furthermore the results by Castellacci (2011) are for Norway, a rather small economy in which one may expect to find different impacts of industry concentration.

The coefficient sign of the market share variables is different across the two surveys. Alternative market share variables have been used based on 3, 4 and 5 digit SIC industry codes as well as using the market share of the enterprise and enterprise group the reporting units belong to, here likewise signs showed large variations and often the market share had to be dropped due to multicollinearty. This implies that the other variables in the model sufficiently capture its variability. For this reason only the first specification includes the market share variable. In the empirical literature in the CDM tradition only the original CDM paper included market share as an explanatory variable and showed it to have a negative and significant impact on the likehood of carrying out R&D and the amount spent on R&D. As for the industry concentration index this information was likely not used in other specifications due to the non-availability of population data which was obtained from the ARD in this work.

Lastly cooperation has a positive impact on the amount of R&D spending confirming that the potential to internalize spillovers makes firms ready to spend more on R&D when they cooperate. This is also in line with previous findings of the literature (Griffith et al. 2006; Janz, Lööf and Peters, 2004; Lhuillery, 2011).

When included the propensity to export has a positive impact on both the likehood of carrying out R&D and the amount spent on R&D both effects being highly significant. As noted in the literature review it is not clear which way the causality runs. That is the same variables that explain the entry to foreign markets explain the likehood of performing R&D and amount spent on R&D and thus exporting is likely to be endogenous. In any case the positive correlation among R&D activities and exporting as identified in some of the literature following the CDM approach (Janz, Lööf and Peters, 2004; Griffith et al. 2006; Castellacci, 2011) is confirmed here.

Including the public support variable also shows it to have a positive impact on both the likehood of spending on R&D and the amount spent (tables 5.12 and 5.13, pages 283 and 284), this effect is quite large and highly significant similar to findings of past literature (Griffith, Huergo, Mairesse and Peters, 2006; Raffo, Lhuillery and

Miotti, 2008). Since this variable is likely to be endogenous and not available for the CIS 5 the results are presented in the next chapter and compared with results where the endogeneity is taken account of.

The significance of the inverse mills ratio is always below 1% which indicates that the use of the selection model is justified and use of straight forward regression would have led to biased results. This of course depends on the underlying assumptions of the model mainly that the error terms have a bivariate normal distribution and that the model is correctly specified.

Let's now turn to the determinants of innovative outputs, where instrumented R&D spending from the Heckman model is used as a measure of "knowledge capital" within the firm. The predicted values from the model without exporting and market share as explanatory variables have been used. Table 4.14 presents the determinants of introducing an innovation (either product or process) the predicted values of which are used as explanatory variable in the third stage of the model.

Table 4.14, Probit model for introducing innovations, mfx (at sample means)

	CIS 4	CIS 5
Observations	13,929	11,574
predicted log(R&D intensity)	0.140***	0.141***
	(0.007)	(0.011)
log (employment)	0.009**	-0.021***
	(0.004)	(0.005)
Absorptive Capacity	0.030***	0.080***
	(0.011)	(0.014)
Wales	-0.002	-0.010
	(0.021)	(0.021)
Scotland	-0.015	0.012
	(0.022)	(0.023)
p industries overall	0.000	0.000
McFadden R^2	0.256	0.215
Link Specification Test	-1.169***	1.059***
Log-likehood	-6410.614	-5588.266

The contribution of knowledge capital in the models explaining innovative outputs is always positive and significant and has a marginal effect at the mean R&D spending level of 0.14 for both the CIS 4 and the CIS 5. This means a 1% increase in R&D spending per employee for the average firm increases the probability of innovating by 0.14%. The marginal effect at the mean found by Griffith et al. (2006) for the UK CIS 3 was 0.273 for their product innovation model and 0.161 for their process innovation model respectively. Region wise neither Scottish nor Welsh firms showed a significantly different propensity to innovate than their English counterparts. Absorptive capacity is as expected an important contributor to the likehood of introducing innovations. This is in line with findings of CDM, Griffith et al. (2006) and Raffo, Lhuiller and Miotti (2008) who show that sources of information or as they have also been termed demand pull factors are important in explaining why firms generate innovative outputs in the UK. It lends support to the idea that absorptive capacity is not just important for producing knowledge capital but also when generating innovations from this knowledge capital[219]. Like previous work the results from this analysis can provide no conclusive evidence as to whether firms' size is conducive for generating innovation outputs or not, that is for the CIS 4 the effects are positive and for the CIS 5 the effects are negative. For instance CDM (1998), Janz, Lööf and Peters (2004) find that size has a negative effect at this stage while Griffith et al. (2006) for the UK find mostly positive effects which albeit are not always significant and likewise the remaining research reviewed in this area identifies a positive relationship (Lööf and Heshmati, 2006; Raffo, Lhuillery and Miotti, 2008; Castellacci, 2011). In any case the size of the effect is fairly small, for instance in the CIS 4 an increase in employment size by 1% at its mean increases the likehood of introducing an innovation by only 0.009%, and for the CIS 5 an increase in employment size by 1% at its mean decreases the likehood of innovating by 0.021%. Thus while the coefficients are significant due to their small size and conflicting signs the likehood of innovating can be considered independent of size for the UK according to these results.

[219] The "transformation" and "exploitation" of acquired knowledge.

Table 4.15, Probit model process vs. product innovation, mfx (at sample means)

Dependent Variable	Process Innovation		Product Innovation	
	CIS 4	CIS 5	CIS 4	CIS 5
Observations	13,929	11,574	13,929	11,574
predicted log(R&D intensity)	0.055***	0.050***	0.129***	0.136***
	(0.004)	(0.005)	(0.006)	(0.010)
log (employment)	0.011***	0.001	-0.000	-0.024***
	(0.002)	(0.002)	(0.004)	(0.005)
Absorptive Capacity	0.030***	0.047***	0.015	0.059***
	(0.007)	(0.006)	(0.010)	(0.013)
Wales	0.014	0.008	0.001	-0.008
	(0.014)	(0.012)	(0.020)	(0.019)
Scotland	0.002	0.030**	-0.017	0.006
	(0.015)	(0.015)	(0.019)	(0.021)
p industries overall	0.000	0.000	0.000	0.000
McFadden R^2	0.182	0.194	0.248	0.202
Link Specification Test	-4.731	-1.662**	-1.872**	1.127***
Log-likehood	-4980.677	-3668.322	-6021.444	-5391.136

The different regression results for explaining various subtypes of innovations are discussed next. The first set is the model for process versus product innovations presented in table 4.15. The explanatory power for the latter model is larger. This would imply that less is known about what drives process innovations. Given that it is the type of innovation that is less visible this is a plausible finding. As argued in the data chapter (2) the CIS is not particularly suited to capture organizational properties of a firm and this is likely to explain why it is more difficult to predict process innovations based on the information it contains. This sort of finding about the "strength" of the product versus the process innovation models is in accordance with the results of the work of Griffith et al. (2006) whose Pseudo R squared for the process innovation model is 0.184 and the product innovation model is 0.258. They also like this work find that the coefficient of predicted R&D intensity is smaller for process innovations. This result is in line with the findings by Parisi, Schiantarelli and Smebenelli (2006) of a lower importance of R&D spending for process innovation. Furthermore as in Harris, Li and Trainor (1995, 2006) it is found that large firms are more likely to be process than product innovators. This provides support to the notion that increased vertical width of activities as a result of size leads to innovations which a smaller firm may classify a product innovation to be categorized as process innovations by larger firms.

Table 4.16, Probit model, services vs. goods innovation, mfx (at sample means)

Dependent Variable	Service Innovation		Goods Innovation	
	CIS 4	CIS 5	CIS 4	CIS 5
Observations	13,929	11,574	13,929	11,574
predicted log(R&D intensity)	0.068***	0.097***	0.072***	0.096***
	(0.005)	(0.009)	(0.004)	(0.007)
log (employment)	-0.010***	-0.030***	0.002	-0.018***
	(0.003)	(0.004)	(0.002)	(0.004)
Absorptive Capacity	0.033***	0.053***	0.003	0.013
	(0.008)	(0.011)	(0.007)	(0.008)
Wales	-0.006	-0.010	0.018	-0.014
	(0.016)	(0.017)	(0.015)	(0.012)
Scotland	-0.010	0.004	-0.004	0.003
	(0.015)	(0.019)	(0.013)	(0.015)
p industries overall	0.000	0.000	0.000	0.000
McFadden R^2	0.178	0.174	0.273	0.261
Link Specification Test	-2.563*	2.224*	2.394*	2.046*
Log-likehood	-5268.802	-4864.369	-4474.707	-3891.052

The explanatory power of the goods innovation models is larger than that of the services innovation models (table 4.16), likewise suggesting gaps in our knowledge, at least when it comes to the usefulness of questions posed in the CIS for capturing the features important for service innovations. The marginal effect of the knowledge capital was of similar size for goods and service innovations and thus suggests an equal importance of knowledge capital in their generation. Absorptive capacity has a significant and positive impact for service innovation while the marginal effect is less for goods innovation and is actually not statistically significant. This result implies that for service innovation absorptive capacity is of greater importance in generating these, since beyond the indirect effect through knowledge capital generated it still requires further absorptive capacity to generate a service that is considered new.

A model of new products versus new processes is not presented here. For a start because as discussed in the data chapter the definitions provided in the CIS diverge considerably from what is considered a radical innovation[220] as they are assessed by the firms themselves. For product innovation firms may simply feel that they are new as a result of a design, specifically the tertiary sector will often aim to differentiate its products providing the appearance of something that is new and thus classified an innovation not previously existent in the market. On the other hand for process innovation firms were asked to assess whether their process was new to the industry rather than the market, unsurprisingly a much smaller percentage of firms indicated that these were "new" (table 2.19 – 2.21, page 64). Secondly whether or not an innovation proves to be major or significant can only be assessed retrospectively, particularly for this reason the figures were treated with caution. Finally there exists no particular literature to the author's knowledge that investigates what causes innovations to be novel or even major, this is an area that will possibly always remain in the 'black box'. Hence a model a a model explaining novelty would have no theoretical foundation..

The last stage of the estimations of the CDM model are presented next, this is the regression explaining productivity (table 4.17). As expected the predicted likehood of innovating has a positive and significant effect on the firm productivity. The size of the coefficients of the predicted probability to innovate suggests that an increase in probability of innovating by 1% increases productivity between 0.37 and 0.18%, this is larger than the effects identified by Griffith et al. (2006) who find the coefficient for product innovation to be 0.055 and for process innovation to be 0.035 both included in the same model explaining productivity for the UK CIS 3. The work of Raffo, Lhuillery and Miotti (2008) finds coefficients of their predicted product innovation to be up to 0.313 in the model explaining logarithmically transformed sales per employee. The investment intensity is as in all other studies

[220] Which in its extreme form only occur very infrequently and can only be judged retrospectively, for which the CIS is not suited.

that have been reviewed positive and highly significant in explaining productivity. The employment size has a positive impact on the productivity. Griffith et al. (2006) and Janz, Lööf and Peters (2004) also find a positive impact, however other researchers' results for the effect of size on productivity are not that conclusive, sometimes the effect is positive and sometimes negative and not always significant (CDM, 1998; Lööf and Heshmati, 2006; Raffo, Lhuillery and Miotti, 2008; Castellacci, 2011). The effect of labour skills is while positive only significant for one skill variable for the CIS 4 and positive and significant for both skill variables for the CIS 5. For the CIS 5 an increase in the percentage of employed engineers and scientists by 1% explains a 0.4% increase in productivity, this effect is highly significant. However this is not confirmed based on the CIS 4 results. The percentage of other degree employees also has a similar sized effect, namely that for each increase of 1% in the number of employees with such a non-engineering or scientists degree there is a 0.4% increase in productivity, again this effect being highly significant. While for the CIS 4 a similar sized effect of 0.2% could be established this is only significant at the 10% significance level. These results compare to a figure of 1.6% found by Crepon, Duguet and Mairesse (1998) or those of Lööf and Heshmati (2006) who have information about the percentage of engineers among the workforce and find that this variable has highly significant effects for both service and manufacturing sector of magnitude 0.3% and 1.0% respectively. Raffo et al. (2008) for the Swiss data get an equivalent coefficient of 0.8% (for percentage of workers with tertiary education) which is highly significant[221] whereas Janz, Lööf and Peters (2004) for the combined German and French CIS 1 data find a coefficient of 0.08% for the effect of a 1% increase in the proportion of graduates employed which is not significant[222]. Productivity is found to be lower in Wales and Scotland with the effects being highly significant.

[221] For France and Spain their skill variable is based on proxies and are hence not presented.
[222] They believe this to be a result of double counting as around half of the personnel employed in R&D activities has a degree. This may also explain why for the CIS 4 our coefficients are not significant.

Table 4.17, OLS regression for productivity - log (total sales/employment)

Sample	CIS 4	CIS 5
Observations	13905	9189
predicted probability of innovating	0.365***	0.175**
	-0.06	-0.07
physical cap/employee	0.099***	0.127***
	-0.01	-0.01
log (employment)	-0.140***	-0.122***
	-0.03	-0.04
Wales	-0.062*	-0.137***
	-0.03	-0.04
Scotland	1.111***	1.289***
	-0.13	-0.12
science and engineers %	0.00	0.004***
	0.00	0.00
other degree %	0.002*	0.005***
	0.00	0.00
p value joint sig. industries	0.00	0.00
R-squared	0.25	0.30

It would have been possible to extend this model to see the different effects of product and process innovations individually. To do so one needs to have strong identifying restrictions to distinguish between the effect of predicted process and product innovations given the similarity of these types of innovations[223] these are difficult to justify. It has nevertheless been done in the paper by Griffith et al. (2006) who use as instruments for process innovation 'information from suppliers' and for product innovation 'information from customers'. Nevertheless the final results suggest that this was not successful as sometimes product and process innovation are not significant and sometimes even have a negative sign. Furthermore it is difficult to replicate their approach here as our interest lies in confirming the impact of absorptive capacity in general and thus the variables they represent cannot be used as identifying restrictions.

The focus of this chapter is the determinants of innovation and it hence lacks a theoretical review of what drives employment, exports and productivity (growth).

[223] As noted repeatedly a process innovation of a larger firm may be the product innovation of smaller firm.

Nevertheless the third stage of the model has been extended including these three performance measures as dependent variables based on the same regression model[224] following Lööf and Heshmati (2006). The results are presented in the appendix 4.8. While for productivity growth (table 4.20) the results are unconvincing (similar to Lööf and Heshmati's, 2006 findings), they confirm the importance of predicted innovative outputs in contributing to employment and exports (tables 4.18 and 4.19).

4.7. Conclusion

This chapter in its second section has provided a review of the factors that have been shown to influence innovative activities by firms. Next the methodology as laid out in the CDM framework has been explicated, summarizing the previous literature that has relied on this framework. Thereafter the econometric approach used to estimate this three stage model of the relationship between R&D, product innovation and productivity was presented explaining how it accounted for simultaneity and sample selection. The following section described the data available for estimating these relationships specifically motivating the use of the previously generated absorptive capacity and appropriation measures. While by and large the coefficients sings and significance for the estimated models were similar for the CIS 4 and the CIS 5 a few variations existed. This was expected due to differences in the reported R&D intensities for the surveys as well as the other varying measurement errors across surveys described in the data chapter. Overall the results provide evidence that factors pointed to in the literature on what determines innovative activities are also important at the firm level in explaining those activities in the recent past for the UK. First of all this is firm size which has a positive and significant impact on the probability of performing R&D and is used as an instrument for identification of the Heckman model. While it had a positive and significant impact on productivity for the second stage model in explaining the likehood to innovate the sign of its coefficients varied across the surveys. Industry dummies are also shown significant in determining both the propensity to carry out R&D and the amount of R&D spending as well as being statistically significant in

[224] Except for explaining employment where it is excluded as explanatory variable.

stage two and three of the CDM model. Regional dummies for Scotland and Wales while included were not particularly significant, though the sign of their coefficients suggests that firms in these regions have generally less innovative inputs and outputs and exhibit lower productivity. The last of these relations was statistically significant. The explanatory variables that are described next except for absorptive capacity were only included in the first stage of the model and thus (apart from exports and market share) used as instruments for knowledge capital. Propensity to export if included has a positive and significant impact on the two outcome variables of the first stage, though the literature is not conclusive on which way the causality runs thus this result is to be treated with caution. Likewise public support has a positive and significant effect in the first stage of the CDM model when included. As shown in the next chapter since it is endogenous the effects are overestimated if this endogeneity is not accounted for. Corporation has also been found important in determining the extent of spending on R&D. Market share could not be verified to have a consistent effect in the first stage of the CDM model. On the other hand the Herfindahl concentration index is confirmed to have a positive impact on the propensity of undertaking R&D and the amount spent on R&D. This finding has only been previously identified for Norway (Castellacci, 2011) but based on data extrapolated from the CIS rather than actual population data as done here which was obtained from the ARD. Foreign ownership has a negative effect on the likehood of carrying out R&D which is albeit not always significant and has no consistent effect on the amount of R&D spending. Appropriation is found to have a positive and significant effect on the propensity to carry out R&D and the amount spent on R&D. Absorptive capacity is likewise shown to have a positive and significant impact in determining 'knowledge' generated within a firm. It is also significant in explaining the likehood to introduce innovative outputs in the second stage of the model but was dropped for identification in the third stage of the model. Both absorptive capacity and appropriation have an inverted U-type relationship with R&D spending. For absorptive capacity this effect has previously only indirectly been shown by Lhuillery (2011), while for appropriation this feature has generally been identified by the empirical literature as for instance reviewed by Dosi, Malerba, Ramello and Silva (2006). However this relation was not previously confirmed using the CDM framework as like for appropriation no continuous variable has formerly been used in such a model. The predicted R&D spending that captures 'knowledge capital' has a positive and significant effect in explaining innovative outputs. In the third stage model predicted propensity to innovate has been shown to have a positive effect on productivity. Likewise firm size and the proportion of people with a degree were shown to have a positive effect. Again industry effects were highly significant. Lastly capital intensity proxied by spending on 'equipment, machinery and software' per employees in the last year of the survey period had a positive and significant effect on productivity.

The main contribution of this chapter lies in investigating recent UK evidence based on an extensive and more comprehensive sample than the only comparable work making use of UK CIS data (namely the third round) by Griffith et al. (2006). They had 1,904 observations available while here 13,836 and 11,438 observations were available due to inclusion of the service sector and firms with less than 20 employees. Extending the analysis to this larger sample and underlying population particularly including service sectors, which is after all the most important sector for the UK, thus provides a more comprehensive picture of what determines innovation in the UK. Furthermore the use of continuous latent variables to capture absorptive capacity and appropriation allowed to confirm decreasing returns to scale for both of these firm attributes. A further contribution to the empirical literature estimating the determinants of innovation is the use of industry concentration index and market share based on population data as obtained from the ARD. This showed the former to have a positive impact on propensity and amount of R&D spending while no consistent effect for the latter could be established.

Unfortunately the variables used to construct these measures were no longer available for the CIS 6, besides as seen in the data chapter the quantitative information specifically R&D intensity shows considerable fluctuation across the surveys as a result of changing measurement errors imposed by changes in the design of the survey. A further measurement error due to the overlap of the surveys leading to potential double counting of introducing innovations makes time series analysis problematic. Measurement errors if consistent should not pose such a big problem for such analysis, however if changing they do not difference out and may lead to spurious correlations being picked up. Likewise the actual sample size for which observations are available is rather small and biased towards larger firms. Also as previously noted Harris (2002) argues that due constant resizing, acquisition and sale of business units using reporting unit data over time is problematic[225]. For these reasons no attempt was made to carry out panel data analysis. Nonetheless it is believed that the results are valid due to the persistence of innovative activities. That is the issue of a lack of causality between the dependent and explanatory variables in the models is not too serious.

[225] Admittedly this can be accounted for to some extent as starting from the CIS 5 binary indicator is included on whether firms changed by more than 10% in size due to mergers or the sale of part of their company.

4.8. Appendix – Alternative 3rd stage specifications

Table 4.18, OLS estimation 3rd stage CDM explaining log(export/total turnover)

Sample	CIS 5
Year	2006
Observations	3208
predicted probability of innovating	0.987***
	-0.26
physical cap/employee	0.085**
	-0.04
log (employment)	-0.05
	-0.16
Wales	0.33
	-0.21
Scotland	1.278***
	-0.49
science and engineers %	0.016***
	0.00
othder degree %	0.00
	0.00
p value joint sig. industries	0.00
R-squared	0.094

Table 4.19, OLS estimation 3rd stage CDM explaining employment level

Sample	CIS 4	CIS 5
Year	2004	2006
Observations	13927	11502
predicted probability of innovating	1.063***	0.491***
	-0.04	-0.05
physical cap/employee	-0.111***	-0.108***
	-0.01	-0.01
Wales	0.02	0.01
	-0.03	-0.03
Scotland	0.075***	0.04
	-0.03	-0.03
science and engineers %	-1.191***	-1.222***
	-0.08	-0.09
other degree %	-0.001***	0.00
	0.00	0.00
p value joint sig. industries	0.00	0.00
R-squared	0.116	0.084

Table 4.20, OLS estimation 3rd stage CDM explaining productivity growth

Sample	CIS 4	CIS 5
Year	2002-2004	2204-2006
Observations	12202	8548
predicted probability of innovating	0.02	-0.022**
	-0.02	-0.01
physical cap/employee	0.00	0.004**
	0.00	0.00
log (employment)	-0.011***	0.00
	0.00	0.00
Wales	-0.01	0.00
	-0.01	-0.01
Scotland	0.00	-0.01
	-0.02	-0.01
science and engineers %	0.00	0.00
	0.00	0.00
other degree %	0.00	0.000***
	0.00	0.00
start-up	0.01	-0.024**
	-0.02	-0.01
merger		0.00
		-0.01
downsizing		-0.033***
		-0.01
p value joint sig. industries	0.01	0.00
R-squared	0.007	0.024

4.9. Appendix – CDM Literature Model Specifications Breakdown

Crepon, Duguet & Mairesse (1998) - French merged data set including accounting information + innovation survey by SESSI				
Dependent	R&D performer	log (R&D spending/employee)	patents/employee; log(innovative sales / turnover)	log (VA per employee)
Instrumented			R&D / employee (+/ *) ; (+/*)	patents/employee (+,/*) alt: innovative sales intensity (+/*)
Size	# of employees (+/*)	# of employees (-/not*)	# of employees (-/*)	# of employees (-/*) ; (+/*)
Industry	18 industry dummies	18 industry dummies	18 industry dummies	18 industry dummies
Market share	(weighted) market share (+/*)	(weighted) market share (+/*)		
Diversification	1/(Herfindahl of firm's business) (+/*)	1/(Herfindahl of firm's business) (+/*)		
Skills				physical capital/employee (+/*) ; (+/*) engineers/personnel (+/*) ; (+/*) administrators/personnel (+/*) ;(+/*)
Technology push -technological opportunities	3 dummies by intensity (+/*)	3 dummies by intensity (+/*)	3 dummies by intensity (+/*); (+/*)	
Demand pull -market demand	3 dummies by intensity (+/*)	3 dummies by intensity (+/*)	3 dummies by intensity (-/*) ; (+/*)	

Janz, Loof and Peters (2004) - CIS 1 of knowledge intensive mfg. Germany and Sweden (separated results shown only)				
Specification	innovators (input & output = 1)	log (innov invest/employee)	log (innov sales / employee)	log (sales / employee)
Instrumented		continuous R&D	innovation investment	log (innovative sales / employee)
		(+/***) ; (+/***)	(+/***) ; (+/**)	(+/***) ; (+/***)
	new to the market	process innovation	productivity (sale/employee)	process innovation
	(+/*) ; (+/not*)	(+/not*) ; (-/not)	(+/***) ; (+/not*)	(-/**) ; (-/not*)
	merged	public funding dummy	public funding dummy	merged
	(+/not*) ; (-/not*)	(+/not) ; (+/not)	(-/not) ; (-/**)	(+/not*) ; (-/not*)
	part of enterprise group	valid patents dummy	part of enterprise group	downsized
	(+/not*) ; (-/not*)	(+/***) ; (+/***)	(+/not*) ; (-/not*)	(+/**) ; (+/not*)
		design registration dummy		
		(-/not*) ; (+/***)		
Size	log(employment)	dropped for identification	log(employment)	log(employment)
	(+/***) ; (+/***)		(-/**) ; (-/not*)	(+/***) ; (+/*)
skills	graduates/employment			graduates/employment
	(+/***) ; (+/***)			(+/not*) ; (+/not*)
				log (capital invest/ employee)
				(+/***) ; (+/not*)
Most important mkt	international < 50 km	international < 50 km		
	(+/***) ; (+/not*)	(-/not*) ; (+/not*)		
network effects (stage 3)	national > 50 km	national > 50 km	1+; 2+; 3+; 4+ sources	export/sales
	(+/**) ; (-/not*)	(-/not*) ; (+/not*)	(alternating/partly*)	(+/**) ; (+/not*)
	international > 50 km	international > 50 km	1+;3+;5+;7+ cooperations	
	(+/**) ; (+/***)	(+/not*) ; (-/not*)	(alternating/partly*)	
Industry	4 industry dummies	4 industry dummies	4 industry dummies	
Cooperation		science and technology	science and technology	
		(-/not*) ; (+/not*)	(-/not*) ; (+/not*)	
		mkt demand	mkt demand	
		(+/not*) ; (+/not*)	(+/not*) ; (+/not*)	
		other firms	other firms	
		(+/*) ; (+/not*)	(-/not*) ; (-/not*)	
Sources			Various	
			(alternating/not*)	

Griffith, Huergo, Mairesse & Peters (2006) - CIS 3 France, Germany, Spain and UK - results for UK shown				
Dependent	R&D performer	log (R&D spending/employee)	Process; product innovation	sales/employee
Instrumented			R&D intensity (+/***) ; (+/***)	process and product innovation; (+/not*) (+/*)
Capital			capital spending/employee (+/***) ; ---	capital spending/employee (+/***)
Size	5 sizebands (+/***)	dropped for identification	5 sizebands (+/partly*), (mostly +/not*)	5 sizebands (+/ *)
Industry	industry dummies (overall ***)	industry dummies (overall ***)	industry dummies (overall **); (overall ***)	
Exporting	most important market (+/***)	most important market (+/***)	dropped for identification	
Cooperation	---	any partners (+/***)		
Appropriation	Formal (+/***) strategic (+/***)	Formal (-/not*) strategic (-/not*)	Formal (-/***);(-/not*) Strategic (+/not*);(-/not*)	
Public Support	Local; National; EU (+/not*);(+/***);(-/not*) National	Local; National; EU (+/not*); (+/***);(-/not*) National		
Demand Pull		Environment Health & Safety Regulations (together not*)	Environment (+/not*) ; (+/not*) Standards (-/not*) ; (-/not*)	
Information Sources		Internal, Uni, Government, Suppliers, Competitors, Customers (together not*)	Suppliers (+/***) ; --- Competitors (+/not*) ; (+/not*) Customers ---, (+/***)	

Loof and Heshmati (2006) - CIS 2 for Sweden separated into services and manufacturing				
Dependent	innovators (input & output = 1)	log (innov invest/employee)	log (innovative sales / employee)	log (sales / employee)
Instrumented			log (innov investment / employee) (+/*) ; (+/*)	log (innovation sales / employee) (+/**) ; (+/not*)
Capital	log (capital/employee) (+/not*) ; (+/*)	capital (+/not*) ; (+/*) export (+/*) ; (+/not*)	log (capital/employee) (-/not*) ; (-/not*) growth rate in main mkt: strong (+/**) ; (+/*) growth rate in main mkt: strong (-/not) ; (-/not***)	log (capital/employee) (+/*) ; (+/*)
Size	employment (+/**) ; (+/*)	employment (+/*) ; (+/*)	log (employment) (+/***) ; (+/not*)	log (employment) (+/not*) ; (-/not*)
skills	engineers / employment (+/not*) ; (+/*) administrators/employee (+/not*) ; (-/not*)			engineers / employment (+/*) ; (+/*) administrators / employment (+/**) ; (+/*)
Competitiveness (1st stage)	quality (+/*) ; (+/*)			
Information sources (3rd stage)	security (+/*) ; (+/not*)		conferences, meetings and journals (+/***) ; (-/not*)	
barriers (2nd step)	trademarks (+/not*) ; (+/*) knowledge content (+/***) ; (+/***) uniqueness (+/***) ; (+/not*)	lack technology (-/*) ; (+/not*) lack personnel (+/not*) ; (+/***)	information technology (-/not*) ; (+/***) suppliers (+/***) ; (+/not*) internal (-/***) ; (-/not*)	offensive innovation strategy (+/***) ; (+/***) defensive innovation strategy (-/**) ; (-/not*)
		external cooperation (+/*) ; (+/***)	new to mkt and cooperated (+/**) ; (-/not*) new to firm not cooperated (+/*) ; (+/*)	process innovation (-/not*) ; (-/not*) organizational innovation (-/not*) ; (-/not*)

Raffo, Lhuillery and Miotti (2008) - CIS 3 for France, Spain, Switzerland (results for these only) + developing countries				
Dependent	R&D performer	R&D spending / employee	product innovation	log(sales / employee)
Instrumented			R&D intensity (+,+,+;*,*,*)	product innovation (+,+,+;*,*,*)
Capital				log (investment/employee) (+,+,+;*,*,*)
Skills				% with tertiary education (+,+,+;*,not*,*)
Size	5 sizebands (+, *)	dropped for identification	5 sizebands (+, partly *)	5 sizebands (-,+,+;*,*,not*)
Industry	Sector dummies	Sector dummies (together *,*,*)	Sector dummies (together *,*,*)	Sector dummies (together *,*,*)
Ownership	domestic group dummy (+,+,-;*,not *,not *)	(+,+,+;*,*,not*)	domestic group dummy (-,-,-;*,not *,not *)	
	foreign group dummy (+,-,-;*,not*, not*)	(+,-,+;*,not*,not*)	foreign group dummy (-,+,-;*,not*, *)	
Public support	receipt dummy (+,+,+; *, *, *)	(+,+,+;*,*,not*)		organizational innovator (-,+,-;not*,not*,not*)
Information Sources		Internal (+,+,+;not*,*,not*)	Internal (+,+,+;not*,*,*)	
		Suppliers (-,-,-;not*,*,not*)	Suppliers (+,+,+;*,*,*)	
		Customers (+,+,+;*,*,not*)	Customers (+,+,+;*,*,*)	
		Competitors (+,+,-,*,not*,not*)	Competitors (-,+,+;not*,*,not*)	
		Universities (+,+,+;*,*,not*)	Universities (-,-,+;*,not*,not*)	
		Exhibitions (+,+,-;not*,not*,not*)	Exhibitions (+,+,+;*,*,*)	
Cooperation		National (+,+,+; not*,not*,not*)		
		International (+,+,+; *,not*,*)		

Castellacci (2011) - CIS 4, CIS 5 and CIS 6 for Norway pooled (presented) as well as unbalanced panel				
Specification	engaged in R&D	log (R&D employ / total employ)	log (innovative sales /turnover)	log (sales/employee)
Instrumented			log (R&D employees / total employees) (+/**)	log (innovative sales / turnover) (+/***) R&D performer (+/***)
			part of a group (+/not*)	part of a group (+/***)
Size	log (employment) (+/***) productivity gap (-/***)	log (employment) (-/***) productivity gap (-/***)	log (employment) (+/***) productivity gap (-/***)	log (employment) (-/***) productivity gap (-/***)
	Herfindahl index (+/***)	Herfindahl index (+/**)	Herfindahl index (+/***)	Herfindahl index (-/***)
market location	categorical, mkts sold to (+/***)	categorical, mkts sold to (+/***)	categorical, mkts sold to (+/***)	categorical, mkts sold to (-/***)
barriers	high costs (+/***) qualified personal lack (+/***) information lack (+/***)	high costs (+/***) qualified personal lack (+/***) information lack (+/***)		high costs (-/***) qualified personal lack (-/***) information lack (-/***)
protection methods			design dummy (+/**) complex design dummy (+/**)	

5. The Effectiveness of Public Financial Support for Private Sector Innovation

5.1. Introduction

The main policy instrument used to stimulate innovation by firms is public R&D funding[226]. However from a market perspective there are concerns as to whether this simply replaces private R&D funding and from a systemic perspective whether this is effective at addressing systemic failures. So the question at hand is whether public support can or cannot be considered a determinant of innovation. For the UK the R&D tax credit introduced in 2000 for SMES and for large firms in 2002 constitutes a major innovation policy change with the number of applications since the introduction of the grant having almost doubled (Figures from HMRC[227]), meanwhile business R&D spending relative to GDP as presented in the introductory chapter (Figure 1.1) showed no notable increase over the last 10 years. The literature surveys by David, Hall and Toole (2000), Hall (2002a) and Jaffe (2002) as to whether government funding is complementary or a substitute to private funding concludes that the evidence is mixed.

The following chapter provides empirical evidence about the effectiveness of UK government financial support that is to stimulate private innovative activities. To the author's knowledge no investigation of this sort exists for the UK, specifically none making use of the information present in the CIS 4 and the CIS 6 about whether a firm has received public financial support for innovation. David et al. (2000) in their review of the literature on the additionality issue argue that no general conclusion about whether public support is effective can be drawn instead evidence needs to be collected in the specific (systemic) setting. They particularly note the lack of studies at the firm level. Hall and Van Reenen (2000) also provide a review of the evidence on the effectiveness of tax credits and argue for further research on the matter particular for countries besides the US. Both papers note that appropriate care needs to be taken to account for selectivity when applying

[226] See for instance Abramovsky, Harrison and Simpson (2004, p14) for a breakdown of the UK budget for innovation support.
[227] http://www.hmrc.gov.uk/stats/corporate_tax/rd-numberofclaims.pdf

direct comparisons of firm performance with and without support. The research undertaken in this chapter which accounts for the issue of selectivity is thus important because while evidence for other countries exists (see Appendix 5.9 for a list) the policy regime as well as the industry mix of those countries is likely to be very different to that of the UK[228].

Two previous studies for the UK exist to the author's knowledge on the issue of the effectiveness of tax credits, one is by Griffith, Redding and Reenen (2001) who simulate the effect of R&D tax credits for the UK using estimates of tax prices elasticity of R&D and the effect of R&D on productivity. They find that in the short run the R&D tax credit may only be effective under certain conditions. However they conclude that GDP gains should substantially exceed the cost of such support. Another work which is based on panel data from a set of OECD countries including the UK by Bloom, Griffith and van Reenen (2002), looks at the effectiveness of (general) tax credits across several countries using panel data from (1979 – 1997) finds that these monetary incentives are effective at stimulating R&D spending. This is based on observations as to the impact of changes in the costs of R&D and subsequent changes in investment in R&D as such it does not address the additionality issue. Similar to the previous work their results suggest that the tax credit is beneficial, with the long run effects being even more substantial. Both of the aforementioned studies have of course not been able to directly assess the impact of the R&D tax credit for the UK as this has only been introduced in 2000/2001, likewise their focus lies on tax credits and not innovation policy per se. So this study is distinct in that it provides evidence about policy effectiveness now that the tax credit is in place but also investigates the overall effect of financial support towards innovation besides the tax credit.

The UK CIS (excluding rounds 5 and recently 7) contains information on which firms in these datasets receive financial public support for innovation. So this chapter contributes to the literature by looking at what this new data can tell us about the effectiveness of public support for innovation. Furthermore it addresses the

[228] Even within countries the policy regimes are changing so quickly that it is very difficult to disentangle the effect of different programs.

aforementioned issue of selectively, that is firms that are in receipt of government support are in general likely to be more innovative in the first place. The way this is dealt with here is by the use of propensity score matching. This approach constitutes estimating a likehood model that explains the receipt of public financial support for innovation. With the use of this model one selects a sample of non-supported (controls) firms similar in properties to the supported (treated) firms and hence differences in innovative performance can be attributed to the receipt of support. Following the recent best practice a regression after matching is applied to control of any remaining heterogeneity among treated and controls (Imbens and Wooldridge, 2009). This is based on the first stage regression of the previous chapter (thus only available for the CIS 4) which serves as a robustness check for the obtained treatment effects on R&D propensity and spending. It allows to confirm the selectivity in the receipt of support and thus comparison of results from the previous chapter with and without controlling for this endogeneity. This has been neglected in those studies following the CDM tradition which make use of public support as an explanatory variable in the first stage of the model (for instance by Griffith et al., 2006 and Raffo et al., 2008). A further novelty found herein is that previous specifications explaining the funding probability have not included direct measures of absorptive capacity as generated from the question about the 'sources of information important for innovation' in chapter 3[229]. The advantage of using the absorptive capacity measure as an explanatory variable for the receipt of public support instead of past innovative activities as done by almost all previous studies (see appendix 5.9 "past innovation", for instance Czarnitzki and Hussinger, 2004, Duguet, 2004 and Aerts and Schmidt, 2006) is that this measure is less biased towards visible R&D activities or the introduction of patents as prevalent in the manufacturing sectors. Propensity score matching allows to predict the impact of government support on innovative performance indicators including both inputs such as R&D spending and outputs such as product and process innovation. The latter have not been used by the literature mostly since they were not available to researchers in the past (Aerts, Czarnitzki and Fier', 2006) and thus their inclusion as performance measures present a further addition to the

[229] While one could expect public support to effect absorptive capacity, since it is a resource that is accumulated over time it is assumed exogenous here.

literature. Compared to the previous chapter the approach followed herein does not require devising complex models whose estimation is not robust to misspecifications. These may occur due to the yet limited knowledge about the innovation process. Further to assessing the effectiveness of public assistance the following analysis helps to identify what types of firms actually receive government support and whether this in line with the aims of UK policy (Busom, 2000), again no previous study has done so for the UK.

The plan of the chapter is as follows. The second section presents the arguments for support of innovation by the government, why this support may be ineffective and the empirical evidence about this concern, which is also termed the "additionality issue". The third section then provides details of the variables that influence the likehood of receiving public support as well as shortly summarizing some of the literature relevant to this work. The next section introduces the propensity score matching methodology. Data tabulations in the fifth section show a breakdown of weighted percentage of firms in receipt of various types of support that can be identified based on the CIS as well as the proportion of firms in receipt of public support in general by region, size and industry. Furthermore a comparison of the innovative performance of firms that receive public support versus that of firms not in receipt of public support is shown. The sixth section then presents the mean differences between the non-treated and treated firms, the propensity score model as well as the resulting mean differences among controls and treated firms and finally the estimated treatment effects. The last section summarizes the chapter.

5.2. Theoretical and Empirical Results about Intervention

The empirical analysis in this chapter is based on information about the receipt of financial support for innovation in the form of 'tax credits or deductions, grants, subsidised loans and loan guarantees'[230]. Hence the following exposition focuses on these types of interventions rather than innovation policy in general.

[230] As defined in the question about public financial support towards innovation found in the CIS 4. In the CIS 6 this has been changed to 'tax credits and deductions, grants, subsidised loans and equity investments'.

David et al. (2000) point out that the most direct type of government subsidy towards private R&D comes in the form of grants targeted at particular projects. The government by choosing to support ventures that they perceive to have a high social return induces firms to undertake them by raising their private rate of return. In the UK this currently includes the 'Grant for R&D'[231] and their equivalents for the devolved administrations such as the SMART Scotland scheme. Another potential way to stimulate R&D is through tax credits on R&D spending which reduces its costs (Metcalfe, 1995; Hall, 2002b). The existing UK R&D tax credit allowance is more generous towards SMEs[232] who can opt for a pay-out if their tax bill is not sufficiently large and who receive a higher credit rate at 175% instead of 135%[233]. In contrast to direct subsidies, here the market is allowed to choose which projects it deems feasible. Besides that specific public support is devised to stimulate firm cooperation. This works through subsidizing cooperation and providing advice to small firms with whom to collaborate and how to set up cooperation agreements. The "Collaborative R&D Scheme" as well as corresponding devolved administrations' policies but also the "EU Framework Programme" which provide financial support towards collaborations are present forms of this type of state intervention. A set of measures that provide loan guarantees and equity funding for firms such as the Small Firms Loan Guarantee Scheme (SFLG), the Regional Venture Capital Funds (RVCFs) or the Early Growth Funds (EGFs) for the UK, also fall under the heading of financial support towards innovation.

As first noted by Samuelson (1954), Nelson (1959) and Arrow (1962) innovative activities can have social benefits exceeding private ones because of positive spillovers. These occur due to the nature of information and knowledge generated by innovation which are not perfectly appropriable (Levin et al., 1987; Cohen, 1995). Hence other firms can imitate innovation, meaning the original innovator cannot fully appropriate the returns from his innovation. Based on this argument

[231] Prior to 2003 this was the SMART Award, see Harris and Robinson (2001) for a review of its effectiveness.
[232] "fewer than 500 employees, **and** either annual turnover not exceeding £100M **or** a balance sheet totalling £86M"
[233] See Harris, Li and Trainor (2009) for an examination of the "use of tax credits to raise the level of R&D investment in a disadvantaged region (Northern Ireland)".

there is argued to be an underinvestment in innovative activities from a social welfare perspective. This is the classic rational for government market intervention. The extent of the spillovers however is disputed (Griliches, 1992; Wieser, 2005; Hall, Mairesse and Mohnen, 2010) and depends on the type of innovation[234] and industry characteristics[235]. Jones and William (1998) for instance using a growth model find that actual R&D investment should be between two to four times present investment for optimal resource allocation. From a theoretical perspective in those areas where appropriability is a problem R&D support is helpful by reducing private costs of the innovator and thereby somewhat correcting for the difference between private and social benefits. This is expected to lead to more projects being undertaken and thus a more socially preferable outcome.

Beyond the appropriation issue noted above, Hall (2002a) reviews the reasons why there exists a wedge between the rate of return that a private firm requires for its R&D and that an external investor requires from the firm. The first ones he identifies are related to asymmetric-information issues. Comparing it with Akerlof's (1970) lemon market, in the market for innovation projects the innovator knows more about his project then potential investors. Hence investors require a higher premium for their funds, particularly from new firms without a track record in innovation. Hall (2002a) points out that enforcing full information does not solve the problems as innovators do not want to disclose their ideas which then could easily be copied. According to his literature review empirical support for this proposition exists. Next he highlights issues of moral hazard involved in the financing of R&D. Specifically there exists a principal agent problem between management and ownership (Jensen and Meckling, 1976). Managers invest in projects beneficial to themselves and are more risk averse in making decisions as they do not reap the payoffs but they do have to face potential bankruptcy. Furthermore Hall (2002a) notes that there is also a conflict between shareholders and bondholders because of their different attitudes toward risk. Lastly due to high leverage particularly in US and UK the lack of visible collateral in R&D projects makes them more costly to firms (Hall, 2002a). So the capital structure too,

[234] Whereas process innovations are difficult to copy for external agents, product innovations are embodied in the product itself and can be to some extent be backward engineered.
[235] See for instance Levin et al. (1987) and Mansfield et al. (1981) regarding imitation costs.

explains why there is a wedge between rates of return required for internal funding and those required by external sources.

The aforementioned problems are particularly relevant for small firms that can less often rely on scale to provide for internal sources of finance in other words they do not have sufficient retained earnings. Small firms are also often simply small because they are start-ups. New firms in turn also face problems in financing their undertakings because they have no track record and thus are viewed sceptically by investors (Hoffman, Parejo, Bessant and Perren, 1998). The counter party will find it difficult to assess the usefulness and risk of projects and err on the side of caution thereby possible inhibiting developments that may be radical in nature but particularly helpful in changing pre-existing technology regimes[236]. Despite these arguments governments often prefer to support firms that have a record of being innovative thereby applying a “picking winners” strategy that has been shown to be harmful for the development of heterogeneity vital for innovation (Metcalfe, 1995), and thus counter to this approach Hall (2002a) argues for support of small cash-oriented firms. Another reason for the support of SMEs comes from Lerner (1999) who notes that it acts as a sort of quality certificate for external investors in the US and thereby also has an indirect effect on firms funding of innovative activities. Empirical evidence that small and medium sized firms are particularly subject to financial constraints rather than a lack of capabilities can be found in Czarnitzki and Hottenrott (2011).

In the UK and the EU part of the public support towards innovation is targeted at collaborative efforts, examples here are the EU Framework Programme and LINK[237], Knowledge Transfer Partnerships and Knowledge Transfer Networks (NESTA, 2006). Support of firm collaborations is provided due to the perception that absorptive capacity is low and appropriation is difficult. In other words small firms are bad at collaborating to internalize the benefits of their research and at taping into other

[236] Though Hoffman, Parejo, Bessant and Perren (1998) find that while many firms report finance being a problem only a small number of firms looking for finance actually found it hard to obtain.
[237] Replaced by the aforementioned “Collaborative R&D Scheme”.

firms' expertise[238]. Absorptive capacity (Cohen and Levinthal, 1990) is a measure of how much firms are able to internalize knowledge generated outside their firm, be it from public research institutions or other firms. This goes back to the idea that spillovers are not costless and hence public support is an effort to reduce the costs involved in these transfers. It also is an acknowledgement that networking[239] lies outside the domain of markets and thus may need public funding (Carlsson and Jacobsson, 1994). Hence beyond just helping firms with appropriability through public support there is also the effort to encourage and facilitate cooperation so that small and new firms stand a better chance at competing. Another motive for supporting collaborative efforts according to Hagedoorn et al. (2000) has been to overcome the "wide disparities between the industrial and technological capabilities" of different regions. They further argue that it has also been a response to a loss of competitiveness in high-technology industries considered to be previously held back through anti-trust policies[240]. Both of these points can alternatively be described as systemic failures.

As with other government investments there is the question whether it achieves anything or is simply deadweight (Harris, Li and Trainor, 2009). After all every firm undertaking R&D has an incentive to apply for support and thereby reduce its cost. Worse, the support if applied at the wrong ends could be distortionary. There is a tendency due to political pressures for governments to assign grants particularly to projects that have high measurable and thus private benefits (Metcalfe, 1995). This strategy of "picking winners" is subjected to government failure in making good choices (Nelson, 1984). Also as Hussinger and Czarnitzki (2004) argue there is no guarantee that innovative activities stimulated by policy are necessarily worthwhile or successful as they are often associated with higher risks than normal projects. The reason is that additional R&D projects are likely to have lower private returns, higher costs or a larger element of risk as they tend to be the ones that firms would have considered next on their list of alternative projects. Nevertheless these projects may have larger social returns than the projects that are undertaken by

[238] See Veugelers (1998) for a review and model of R&D collaboration and Kamien and Zang (2000) for an extension incorporating absorptive capacity.
[239] See for instance Powell and Grodal (2005) for a review on the role of networks for innovation.
[240] Similar points are found in Jorde and Teece (1990) with respect to US Antitrust policies.

firms. The past empirical evidence about whether public support is effective, as for instance summarized in the surveys of David et al. (2000), Hall and Van Reenen (2000) and Aerts, Czarnitzki and Fier (2006) seems inconclusive. The findings of these works are now discussed in turn.

David et al. (2000) review the state of the econometric work on the additionality of public support towards private R&D. To start off they caution that their survey only looks at effects of public support on private R&D which is only an innovative input and hence only an imperfect proxy of innovation. This is mostly due to a general bias of studies towards the use of this widely held information as opposed to the use of other measures of innovative performance. Generally the results from the literature are somewhat conflicting and do not allow for a straight forward conclusion on the matter. David et al. (2000) suggest that in parts this can be explained by the differing settings such as time, country and industry scope of the studies. In order to be able to place the past research they draw up a marginal cost benefit analysis framework. Using this they explicate the various channels through which government funding works alternating between complementary or substitution effects. They conclude that differences in settings may have caused different channels to be dominant and thus lead to the somewhat conflicting results of the literature. They find in about two thirds of the cases complementary effects particularly at the firm level. They also suggest that due to this, evidence on the matter should always be handled within its setting (nationwide, regional, firm level, etc.) and thus also requires investigations at the various levels at which policy may apply. Further they note the problem of selectivity of government support which is mostly just assumed exogenous in the research they have reviewed.

Another major review of pre 2000 work has been conducted by Hall and Van Reenen (2000). They specifically look at the effect of R&D tax credits. Starting out with a description of the variations in R&D tax credits across countries and time they try to find out whether the perception of seemingly low responsiveness of private R&D to this stimulus is correct. From the studies they reviewed they conclude that there is strong evidence that R&D tax credits are effective. They advocate further research particularly outside the US to establish the effectiveness of varying tax treatment which they perceive as the present tool of choice for stimulating innovative activities.

A more recent review of the literature comes from Aerts, Czarnitzki and Fier (2006). They specifically look at the work that has tried to address the selection problem identified by David et al. (2000). Laying out the various econometric approaches that can be followed they categorize work by whether it deals with input additionality (R&D) or output additionality (productivity and patent counts). These two may be distinct for two reasons according to them. First an increased demand for R&D inputs may cause its price to rise thus at least part of the identified increase in the value of R&D inputs may simply be due to its price inflating. Secondly as projects that money is spent on are next best their expected returns are likely to be lower than their input costs may suggest. They also look at studies that investigate the effect of public support on cooperative research, and while the theoretical arguments in this area are inconclusive the recent empirical evidence seems to suggest that this sort of support is useful. They conclude that more research is needed particularly studies aimed at measuring the effect of support on innovative outputs. Related to this they highlight availability of such information in the CIS. A list of studies particularly making use of CIS and similar data is found in the appendix 5.9 and these works findings are referenced in the subsequent section.

5.3. Determinants of the Receipt of Public Support

Let’s turn to the factors expected to determine the likehood of receiving public support for innovation as these shall guide the specification of the propensity score model to create a matched sample. On the one hand these are a firm’s characteristics that make it apply for support and on the other hand a firm’s properties that cause policy makers to grant such support to the applicant. Both of these tend to be similar and cannot be distinguished in the analysis as information is only available for who is granted support and not for who applies for support. Thus in the ensuing discussion the variables that influence the receipt of support are discussed from both angles, so to speak the demand and supply side of government support for innovation. Where relevant these are related to specific UK innovation policy.

The past literature has shown size to be an important determinant of receiving public support (Czarnitzki and Hussinger, 2004; Aerts and Schmidt, 2006; Clausen, 2007; Gonzalez and Pazo, 2008). This is in line with the Schumpeterian Hypothesis that the likehood of carrying out innovative activities increases more than proportionally with size, thus one would expect to see larger firms to more often apply for support of such activities. On the other hand it is often due to a lack of finance as well as higher costs that small firms are inhibited from innovating (Hall, 2002a). As a result much support in the OECD countries is directed towards SMEs that face these problems (Hall and Van Reenen, 2000). The impact of size on the receipt of public support depends thus on which of these opposing demand and supply side effects is stronger. The empirical literature mostly finds that public support is still biased towards larger firms (Almus and Czarnitzki, 2003; Aerts and Czarnitzki, 2004; Blanes and Busom, 2004; Czarnitzki and Hussinger, 2004; Duguet, 2004; Aerts and Schmidt, 2006; Clausen, 2007; Hussinger, 2008) however none of this evidence is for the UK where specific policies are directed at SMEs such as the Grant for R&D[241], Innovation Vouchers[242] as well as the more generous R&D tax rebate for SMEs which is paid out to SMEs if they have an insufficient tax bill.

As discussed in the previous chapter the industry sector a firm belongs to is likely to have an effect on the technological opportunities and potential spillovers that a firm can benefit from. Furthermore it has been shown that industries exhibit heterogeneity in the likehood of carrying out innovative activities and the amount spent on such activities. Therefore firms from different industries can be expected to have varying affinity to apply for government innovation support. On the other hand governments try to support certain industries they see as important for the countries growth and competitiveness prospects or for national interest, these

[241] This arose by integrating the SPUR, SMART and Regional Innovation Grant schemes.
[242] Though it is not clear whether firms will interpret it as financial support, while it is in the sense that the vouchers represent monetary value that can be spent on innovative activities.

include defence[243] and life science industries for the UK[244]. Most of the studies reviewed (for example Busom, 2000; Almus and Czarnitzki, 2003; Duguet, 2004) have accounted for these factors using industry dummies. Those studies that have omitted this information in their model specification have done so due to unavailability or width of data being limited to specific industries (Lööf and Heshmati, 2004; Clausen, 2007; Hussinger, 2008).

Czarnitzki and Hussinger (2004) and Hussinger (2008) have included a regional dummy for East Germany, while Herrera and Nieto (2008) show that the coefficients of the factor determining likehood of receiving public support towards innovation vary across regions in Spain. The reason for differences across regions is the selectivity of government support towards certain disadvantaged ones. The differences in regions' ability to innovate has been highlighted by the regional innovation system literature (Cooke, 1992, 2005, 2006; Cooke, Uranga and Etxebarria, 1997; Asheim and Isaksen, 1997, 2002) as well as the literature on regional growth (see Harris for a review, 2011)[245]. Such disparities are also expected to be observed in the UK where innovation policy was until April 2012 partly in the hands of Regional Development Agencies (RDAs)[246] in order to provide tailored support for particularly disadvantaged regions as well as the devolved administrations having their own economic policy agendas.

Firms that export tend to be more competitive as argued in the previous chapter. These firms that work to maintain the competitive advantage of a country could thus be expected to be more likely to receive government support. Also support of such firms is in line with governments' objective for public support to maintain and

[243] Not present in the CIS though.

[244] Cooperation between BIS and Office for Life Sciences in 2009 to stimulate businesses in the area of Life Sciences by enhancing infrastructure; UK Investment Fund (founded in 2009) is a fund investing in technology based businesses including digital and life sciences, clean technology and other advanced manufacturing; also see Hauser (2006) and the Sainsbury Review (Lord Sainsbury of Turville, 2007).

[245] Though as Harris and Trainor (2011) find the problems that for instance Northern Ireland face are related to its capabilities rather than its resources, which is why financial support towards innovation that is discussed here may be ineffective. Whereas Czarnitzki and Hottenrott (2011) for Germany find limited financial resources rather than capabilities to be the problem of SMEs.

[246] These are now replaced by Local Enterprise Partnerships who will maintain a regional dimension to innovation policy, though without control and funding by central government.

enhance its international competitiveness[247], though it is not a direct selection criterion for any support program in the UK. Thus at least based on demand side arguments exporting should increase the likehood of receiving public support. Past research has mostly shown that indeed a positive correlation exists and for part of the studies this effect is significant (Aerts and Czarnitzki, 2004; Czarnitzki and Hussinger, 2004; Kaiser, 2004; Clausen, 2007).

Foreign ownership has generally been thought of as having a negative impact on the likelihood of receiving public support as being foreign owned may disqualify the firm from receiving support. Another reason for a negative impact of foreign ownership on the likehood of support is that the main research of a foreign owned firm may as argued in the previous chapter be carried out in the home country. At least partial evidence for the proposition that the propensity to carry out R&D is lower for foreign firms was found. On the other hand increasing competition among countries to attract the R&D activities of MNCs is taking place (Dittmer-Odell, 2001). So while from the demand side one may expect the likehood of applying to be lower for foreign owned firms from the supply side it is not clear in which direction the selection leans. The studies that have been reviewed have generally found that firms that are foreign owned are less likely to be in receipt of public support for innovation (Busom, 2000; Aerts and Czarnitzki, 2004; Blanes and Busom, 2004; Lööf and Heshmati, 2004; Aerts and Schmidt, 2006; Clausen, 2007; Hussinger, 2008).

Another variable thought to affect the likehood of receiving government support is firm age. It is expected that older firms due to their track records and experience in applying for public support find it easier to make a successful application. Strictly speaking then age in this case is a proxy for accumulated capabilities. On the other hand it could be argued that older firms are less likely to carry out (risky) innovative activities possibly related to being in a later stage of the product life cycle (Almus and Czarnitzki, 2003). The findings on the relation between likehood of receiving support and age are mostly positive or not statistically significant (for

[247] For instance EUREKA (Seventh Framework Programme), SMART and SEEKIT Scotland scheme and R&D Grant in Scotland are directed towards projects that enhance international competitiveness.

example Busom, 2000; Almus and Czarnitzki, 2003; Czarnitzki and Hussinger, 2004; Heijs and Herrera, 2004). From the supply side perspective some programs specifically target start-up firms[248] as they are likely to find application for extra finance difficult given their lack of a track record in other words they are particularly prone to be affected by market failures (Blanes and Busom, 2004). Counter to this argument for support of young firms the previously noted effect of picking winners with track records in innovation is positively related to the age of a firm. So as for size the effects may go both ways.

Being the member of an enterprise group is expected to have a positive impact on the likehood of trying to innovate, for one due to potential diversification allowing for decreased risk exposure (Nelson, 1959) and also because like large firms these firms may be able to tap into the resources of the enterprise group they are part of both in terms knowledge about and experience in innovation as well as applying for support. Thus one would expect them to be more likely to apply for support. In line with this thinking Aerts and Czarnitzki (2004) and Czarnitzki and Hussinger (2004) find a positive impact of being part of an enterprise group though this is not statistically significant, meanwhile Clausen (2007) identifies varying signs for his enterprise group variable.

Another variable believed to influence the likehood of receiving public support is whether firms cooperate. The UK scheme targeting collaborations is called exactly that “Collaborative R&D Scheme”[249] but also the EU Framework Programme targets collaboration among agents in different countries. Firms in collaboration are also likely to have advantages in the application for support similar to larger firms in that they have more accessible expertise at hand to carry out and qualify for government support. While Heijs and Herrera (2004) show collaboration to have a positive impact on the likehood of receiving public support for innovation in Spain in a later paper Herrera and Nieto (2008) find it may also have negative effects though the later effects are never statistically significant.

[248] For instance the Small Business Research Initiative (SBRRI) and funding of “Enterprise Areas”, but also the R&D tax credit helps small start ups that have not generated taxable profits as well as funding of university spin-offs.

[249] Formerly this was the LINK scheme; covers 25%-75% of the costs of the project cost.

Previous specifications of what determines the receipt of government support for innovation have included information on past R&D activities such as the existence of R&D departments and having registered patents (Aerts and Czarnitzki, 2004; Blanes and Busom, 2004; Czarnitzki and Hussinger, 2004; Duguet, 2004; Clausen, 2007; Hussinger, 2008). Nelson and Winter (1982) for instance argue that established organizational routines of successful innovators are advantageous for future innovative activities. In line with this argument it has been observed that the same firms tend to repeatedly receive government support (Lichtenberg, 1984). This can be interpreted as a policy of building national champions, where a track record of innovation success is used by policy makers as selection criteria for further support. On the other hand from the demand side perspective one could argue that some firms simply have more expertise in the application procedure. Thus firms with past innovative activity are expected to be more likely in receipt of public funding both from a supply and demand side perspective and the aforementioned literature array has empirically confirmed this proposition.

Having reviewed the factors that influence the likehood of receipt of public support a short description of some of the aforementioned articles and those which have influenced the ensuing work follows. Whereas Blanes and Busom (2004) investigate the support programs for Spanish manufacturers from different government institutional levels Clausen (2007) looks at the impact of overall government policy in Norway. Both articles contend that there is a lack of evidence as to what determines the receipt of support for innovation. Blanes and Busom (2004) use a multinomial logit modelling the number of programs a firm participates in whereas Clausen (2007) uses as singular logit model estimating the factors that influence whether firms receive public support at all. Both papers argue that comparing this to the government policy objectives allows evaluating whether its aims are achieved or whether one may need adjustment of support selection. As a result of modelling participation one can thus identify barriers that cause failure to support targeted firms. They find that participation is positively influenced by being large, export orientated with developed innovation capabilities, and this leads Clausen (2007) to conclude that subsidies are given out mostly to "national champions".

Similarly both Blanes and Busom (2004) and Clausen (2007) show that companies without prior innovation capabilities and international growth potential have been neglected by the support programs and hence they argue that the systemic nature of innovation and market failures have not been properly addressed. They also note that heterogeneity of the support programs may in part explain the mixed results of past studies on additionality as this is not accounted for mainly due to data limitations. Hence detailed information about the exact support programs in which firms participate should be made available for proper policy assessment[250].

Czarnitzki and Hussinger (2004) provide an example of how to use nearest neighbour matching to establish whether German R&D support is effective. Their study is based on the Mannheim Innovation Panel which is the German equivalent of the CIS. They reject both partial and full crowding out based on their results. They can analyse the former as they have information on the monetary size of the public support towards innovation. Similar studies using nearest neighbourhood matching have been conducted by various authors for different regions. Among them are Duguet (2004) who uses French panel data collected from 1985 to 1997 for his work or Gonzalez and Pazo (2008) who use an unbalanced panel dataset of Spanish manufacturing firms from 1990 to 1999 in order to investigate poor Spanish R&D performance despite large financial support. Aerts and Schmidt (2007) use CIS data from both Germany and Flanders for a comparison as they are argued to have similar innovation policies while Aerts and Czarnitzki (2004) use CIS3 data for Flemish firms. Herrera and Nieto (2008) have investigated the Spanish survey on Business Strategies from 1998 to 2000 with the specific aim of detecting if business support has different impacts depending on whether firms are located in the periphery or the core. Only Gonzalez and Pazo (2008) and Aerts and Czarnitzki (2004) look at stimulation by public support for all firms, the rest of the studies that have been identified restrict their analysis to samples of firms carrying out R&D[251]. The later more conservative approach thus indirectly assumes that

[250] Unfortunately this sort of information is not available from the CIS either, also likely a result of the frequent changes in available support policies.

[251] Aerts and Czarnitzki (2004) explain that looking at the R&D active sample only means that one is cautious about whether public support actually leads to more firms carrying out R&D activities. Thus one takes the somewhat conservative view that government intervention only leads to firms that already undertake R&D to spend more on it.

government support does not stimulate firms to start innovative activities as a result of the support but only increases their innovative activities. Though this assumption is mostly a result of data being limited to those firms with innovative activities. Similar to Clausen (2007) most of them find that large, international firms with more technological knowledge and experience are at an advantage when attracting public support. The majority of these studies conclude that public support towards innovation stimulates firms' innovative activities for their respective time and regional settings.

5.4. Methodology

One cannot use a straight forward regression to check the significance and sign of a public support variable in explaining innovative performance as it is likely to be endogenous. This is because support is not randomly assigned but as described in the preceding section also based on factors that explain innovative activities in the first place (David et al., 2000, Klette, 2000). For instance government programs are likely to be biased towards firms that have a track record in innovation as well as towards small firms due to financing problems they face and their importance for employment (see Hall 2002a). Both of these factors are determinants of innovative activity by firms. Heckman et al. (1999), Blundell and Costa-Dias (2000) and Jaffe (2002) provide surveys as to what econometric methods are applicable in this sort of situation, they include the use of the Heckman selection model, instrumental variables as well as propensity score matching. The former two however require at least one valid instrument for identification which does not affect innovative activities while influencing the receipt of public support. Such an instrument is difficult to justify though on theoretical grounds (Aerts, Czarnitzki and Fier, 2006)[252]. Aerts et al. (2006) concede that convincing instrumental variable applications are rare to find[253].

[252] Though one could use system GMM with panel data, however as noted previously the CIS dataset does not yet seem suitable for use in panel data analysis.
[253] For instance Hewitt-Dundas and Roper (2010) use plants' receipt of public support for process development, R&D and capital investment as an instrument for the receipt of public support for product development justifying exogeneity on a Wald test which they however do not present. Another example is Kaiser (2004) who use as exclusion restriction, that is factors related to probability of receipt of R&D subsidy but believed unrelated to private R&D: fiercest competitor are locally oriented firms, nationally oriented firms and multinationally oriented firms and at least partly publicly owned firms.

Imbens (2004) argues that matching estimators are the first choice tool to evaluate policy. Unlike regression models where distributional assumptions are restrictive and thus robustness becomes a concern, propensity score matching as Aerts et al. (2006) point out does not require specification of a functional form. Propensity score matching is used to find out the effect of government programs, previously often for labour support, on some performance measure, innovative activity in the case of this work. What one establishes with this method is the so called average treatment effect on the treated (ATT)[254].

$$\alpha_{TT} = E(Y^T - Y^C \mid S = 1) \tag{5.1}$$

Where Y^T is the potential innovative performance such as R&D spending for firms in receipt of support and Y^C is the potential outcome if they do not receive support. S is a dummy variable that takes the value of 1 if the firm receives public support and 0 if it does not. As this is a purely hypothetical situation one needs some sort of estimator for the counterfactual situation. This is particularly an issue if the available data is of cross sectional nature which means one could not use observations where the support was not yet in place to calculate its effect[255]. It is not valid to solve the above by equating:

$$E(Y^C \mid S = 1) = E(Y^C \mid S = 0) \tag{5.2}$$

and thus have the ATT as:

$$\hat{\alpha}_{TT} = E(Y^T \mid S = 1) - E(Y^C \mid S = 0) \tag{5.3}$$

where $E(Y^T \mid S = 1)$ is estimated by the sample mean of Y for the subsidized firms, since equation 5.2 only holds if the receipt of public support towards innovation is randomly assigned which as argued in the previous section is not the case. Matching methods can generate an estimator of the counterfactual $E(Y^C \mid S = 1)$ to allow one to find out the inducement effect of the public support. The downside to this approach is that the underlying assumptions for propensity score matching discussed shortly are very strong and cannot be checked. To increase the confidence that these assumptions hold as well as to ensure good matches are achieved a large number of observations is required to be able to find a suitable

[254] Though one may also be interested in other treatment effects (see Blundell and Costa Dias, 2009).
[255] In this case one would have to account for potential growth effects though.

control for each treated individual. In other words a large amount of data is required both in terms of observations and explanatory variables.

As noted the matching estimator overcomes the problem one faces in a non-experimental setting of estimating equation 5.1 by relying on the conditional independence assumption (CIA) suggested by Rubin (1977):

$$Y^T, Y^C \perp S \mid X = x \tag{5.4}$$

As before Y is the outcome such as innovative activity, T denotes treatment and thus receipt of public support and C stands for the control group while S is the treatment dummy. Equation 5.4 implies that the receipt of public support should be independent for firms with the same set of exogenous characteristics $(X = x)$:

$$E(Y^C \mid S = 1, X = x) = E(Y^C \mid S = 0, X = x) \tag{5.5}$$

In other words differences in firms' innovative performance are purely due to the public support. Thus either one needs to have information on all factors that influence the selection status or those that are not observable are related to those that one can observe and thus can be used to control for them. A further requirement is that for each firm the probability of receiving a subsidy lies between 0 and 1. This means firms with a certain set of characteristics should not all have the same treatment status. Conditional on the observed X, the probability of obtaining a subsidy is thus bounded from 0 to 1:

$$c < P(T = 1 \mid X = x) < 1 - c \text{ where } c > 0 \tag{5.6}$$

As this is not sufficient to ensure that all treated firms can be matched to a non-treated firm, the last assumption for carrying out this procedure is the common support restriction. It requires there to be enough firms with a variety of attributes in the sample so as to be able to find a "similar" counterpart in the non-treated population. Thereby the problem of a lack of the counterfactual is overcome. When these assumptions hold the average treatment effect on the treated is:

$$\alpha_{TT} = E(Y^T \mid S = 1, X = x) - E(Y^C \mid S = 0, X = x) \tag{5.7}$$

Which can be estimated based on the sample means of the treated and the control group.

As noted one to one matching generates a twin for every firm based on the observable characteristics assuming that the unobservable ones are similar (Rubin 1973, 1977). In fact Rosenbaum and Rubin (1983) show that one does not have to find a perfect match on all the observable variables but just needs to generate a propensity score, in this case the probability of receiving public support, and match firms that have the closest propensity score. The advantage of this is making a choice based on a single index as to what constitutes the control group rather than basing it on a whole range of variables. Thereby one overcomes the so called “curse of dimensionality”. An extension to this approach has for example been proposed by Lechner (1999), he suggests the use of “hybrid matching”. This consists of filtering the potential matches by characteristics such as industry dummies and potentially size dummies. Various other extensions have been proposed to this procedure including criteria of propensity score proximity, so called “calliper matching” and using all control group observations as controls, weighting them depending on how close they are to the treated firms, which is termed Kernel matching (Heckman, Ichimura and Todd, 1998; Smith and Todd 2005). These approaches are particularly useful for small samples to overcome the problem of poor matching that is not finding close enough observations in terms of propensity score when using the nearest neighbour. Nearest neighbour matching that is used here means that one matches treated firms with firms that are closest in terms of Mahalanobis distance between respective propensity scores and possibly other matching arguments (hybrid matching). This can be done either replacing the matched control or by dropping it so it is no longer available for matching with other treated observations, the later method is called a one-to-one matching without replacement. With replacement this leads to better matching as more observations are available in the control group but now t-statistics are biased and thus have to be corrected. There are three further criteria identified by Smith and Todd (2005) to ensure that propensity score matching is valid. Firstly they point to the importance of having the same dataset used for participants and non-participants. There is also the question as to whether there is enough information in terms of variables to be able to model the receipt of support. Lastly following the aforementioned “hybrid approach” supported and controls should come from the same market.

A recent development is to conduct regression on the outcome variable for the matched sample, including a treatment dummy as explanatory variable (Imbens and Wooldridge, 2009). While the matching is supposed to control for heterogeneity among treated and non-treated firms there may still be significant differences in the distribution of variables for firms in the treatment group versus those in the control group. The regression after matching is to control for such differences. Of course this sort of approach requires a correctly specified model used in the regression to explain the innovative performance measure, an issue that the matching approach is supposed to overcome in the first place.

Breakdown of procedure followed (adapted from Czarnitzki & Hussinger, 2004)

Step 1: get propensity score from a probit model specification.

Step 2: satisfy common support condition: remove observations from treatment group that have propensity score beyond the maximum of the propensity score in the control group.

Step 3: take one individual from the treated firms.

Step 4: calculate Mahalanobis distance between this firm and all non-subsidized firms in order to find the most similar control observation.

$$MD_{ij} = (Z_j - Z_i)'\Omega^{-1}(Z_j - Z_i) \tag{5.6}$$

Vector Z is the propensity score and Ω the empirical covariance matrix of arguments based on the sample of potential controls, conditional on the firm being in the same industry.

Step 5: take the observation with minimum distance from the sample.

Step 6: repeat steps 3 to 5 for all observations on subsidized firms.

Step 7: from matching comparison group, the average treatment effect on treated is the mean difference of the matched samples

$$\alpha_{TT}^{M} = \sum_{i} \frac{1}{N^{T}} \left[Y_i^{T} - \hat{Y}_i^{C} \right] \tag{5.7}$$

where $\hat{Y}_i^C$ is counterfactual for firm i.

Step 8: if using sampling replacement to estimate counterfactual situation ordinary t-statistic mean differences are biased which is corrected using Lechner's (2001) method of calculating an estimator for an asymptotic approximation of the standard errors (Czarnitzki and Hussinger, 2004).

$$\text{var}(\hat{\alpha}_{ATT}) = \frac{1}{N_1} Var(Y^T \mid S = 1) + \frac{\left(\sum_{j \in I_O} (w_j)^2\right)}{(N_1)^2} \bullet Var(Y^C \mid S = 0) \tag{5.8}$$

[256]

Where N_1 is the number of matched treated individuals, w_j is the number of times individual j from the control group has been used.

Step 9: as robustness check the Heckman model specified in the previous chapter is rerun based on the matched sample for the CIS 4. The receipt of public support is included in both stages. These coefficients can then be compared to the previously obtained treatment effect (for R&D spending and R&D propensity only though).

[256] Taken from Caliendo and Kopeinig (2005).

5.5. Data

Table 5.1, List of variables & expected relation to receipt of public support

variable	dataset	exp. sign	description
log(employment)	IDBR	positive	number of employees in the enterprise
SME	IDBR	-	less than 500 employees and turnover up to £100M turnover
Export	CIS	positive	export dummy (1=exporter)
Foreign ownership	IDBR	unclear	foreign owned dummy (1=foreign owned)
New entrant	CIS	unclear	firm was recently established (1=new entrant)
Absorptive capacity	CIS	positive	measures past innovative activity (recalculated for innovation active enterprises)
Cooperation	CIS	positive	cooperation dummy (1=cooperated)
"divisions"	IDBR	varying	industry dummies (division)
"regions"	IDBR	varying	dummies for Wales, Scotland, Northern Ireland
Innovators	CIS		introduced product and / or process innovation
Product Innovators	CIS		introduced product innovation
Process Innovators	CIS		introduced process innovation
Goods Innovators	CIS		introduced goods innovation
Service Innovators	CIS		introduced service innovation
Cooperative Innovation	CIS		introduced innovation together with other enterprise
Wider Innovators	CIS		at least one wider form of innovation carried out
Wider Innovation Intensity	CIS		factor generated from questions about wider forms of innovation
Design	CIS		registered an industrial design (CIS 6 only)
Trademark	CIS		registered a trademark (CIS 6 only)
Patent	CIS		applied for patent (CIS 6 only)
Copyright	CIS		produced material eligible for copyright (CIS 6 only)
R&D performers	CIS		performed extra and / or intramural R&D (over whole survey period)
R&D spending / sales	CIS		intra and extramural R&D spending (in last year of survey period) / sales
R&D spending / employee	CIS		intra and extramural R&D spending (in last year of survey period) / employees

As detailed in the 2nd section the propensity to export, foreign ownership status, industry sector, region, firm size and the use of cooperation partners are expected to have an impact on whether enterprises receive support for innovation (see table 5.1). Besides that rather than using past innovativeness as an explanatory variable as done by many of the studies that were reviewed, this work employs the previously generated absorptive capacity measure instead[257]. This approach is rationalized as follows. Firstly there is no data available in cross sectional use of the CIS about past innovative activity. Absorptive capacity however is built by engaging in innovative activities (Cohen and Levinthal, 1990). Hence firms with absorptive capacity must have carried out innovative activities in the past. It can thus be used as a proxy for these. The reason why past innovative activity is likely to have a positive impact on the likehood of receipt of public support is that governments apply a “picking winners” strategy when they choose whom to support. Past innovative activity records are thus a signal to the government that the firm is likely to be successful in its undertaking. The demand side argument for firms with absorptive capacity to be more likely to apply for public support is that these firms by definition have better access to external knowledge which should increase their awareness and expertise in applying. Lastly the most important government support for the UK in terms of spending is the R&D tax credit to which firms qualify themselves partly through their balance sheet but mostly through spending on R&D, which as pointed out throughout the thesis is a fairly persistent activity related to a firm’s absorptive capacity.

The information on the receipt of public support is only available for the CIS4 and the CIS6 thus this analysis can only be carried out for these two datasets. Furthermore the matching is only carried out for firms that are considered innovation active[258] according to the CIS 6. This is because it is limited to those firms that have all the explanatory variables available as well as the information about the receipt of public support and the information from which the absorptive capacity measure is generated is only available for innovation active firms for the CIS6[259]. Thus computed treatment effects are likely to be smaller than if using the full sample. Likewise all of the literature that has been cited here apart from Aerts

[257] The absorptive capacity measure was recalculated for all innovation active firms since this information about the rating of information sources for innovation was only available for those firms in the CIS 6. Nevertheless around 20% of the innovation active in the CIS 6 did not respond to this question meaning a large number of observations were lost for subsequent analysis.

[258] Defined as those that either introduced a product or process innovation or that had ongoing or abandoned innovative activities or that indicated to have performed wider forms of innovation.

[259] The absorptive capacity measure was thus re-obtained for innovation active firms only so that it is again centred at 0 for the average of the firms. This means it is ignored that government support may stimulate firms that are non-innovation active to become innovation active (product, process or wider innovators) according to CIS 6 definition.

and Czarnitzki (2004) and Gonzalez and Pazo (2008) only looked at samples of firms with innovative inputs (namely R&D spending) in the first place and thus have been even more restrictive by looking only at firms with formalized innovative activities. To have more comparable results with the literature findings the matching is carried out a second time for firms that have positive R&D spending to see how different the impact is on the estimated treatment effect for R&D intensity at the expense of losing a considerable part of the observations.

The CIS 4 and the CIS 6 section on the types of 'financial government support towards innovation' that enterprises have received, includes information whether firms have received support through 'local / regional authorities' or from 'central government / devolved administrations' or from 'the European Union'. The exact wording of the question is: "During the three year period (of the survey), did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deduction, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector under contract."[260,261]. It is of course not clear whether firms' interpretation of this sort of question is correct since as pointed out in the data chapter what is understood as 'innovation activities' is not clearly specified in the survey. However it is hoped that the question by itself only caused firms that have substantially benefited from financial support towards innovation to answer in the affirmative. For the CIS 4 support from 'central government' and 'devolved administrations' are part of one question, whereas for the CIS 6 the later clause was left out. Thus all support from devolved administrations could now be expected to have been reported under support from 'local or regional authorities'. It may also be that some firms in the CIS 4 first being presented with the option of 'local or regional authorities', replied to both this option and the next one which clearly includes 'devolved administration' positively if they received support from devolved administration thus leading to double counting. Note that there is no information on the amount of

[260] The word "enterprise" was replaced by "business" and the word "loan guarantees" was replaced by "equity investments" in the CIS 6.
[261] At this point the reader is reminded of the discussion in section 2.4 about the lack of a clear definition of how this term is to be understood.

subsidies or tax credits received in the CIS, thus one can only analyse the overall effect of policy from all levels of government and not look at the pound by pound impact this may have had on innovative input spending.

Table 5.2, Weighted % of firms in receipt of public support by government level

	CIS4	CIS6	CIS4	CIS6
	Whole Sample		Innovation Active	
Wales, Scotland & Northern Ireland	3570	2694	1778	1240
Local or regional authorities	9.1	8.5	18.2	22.4
Central government & for CIS 4: or devolved administrations	6.2	1.9	15.4	6.4
-Tax credit	2.8		6.5	
European Union	1.2	1.6	3.4	4.4
-Framework program	0.7		1.4	
Total	11.5	9.9	26.2	26.8
England	11733	8743	6458	4332
Local or regional authorities	3.4	3.7	6.2	7.3
Central government & for CIS 4: or devolved administrations	4.9	2.3	9.6	5.4
-Tax credit	3.2		6.3	
European Union	1.0	0.9	1.9	2.1
-Framework program	0.7		1.0	
Total	7.1	5.7	13.9	12.1
UK	15303	11437	8236	5572
Local or regional authorities	4.3	4.4	8.8	10.6
Central government & for CIS 4: or devolved administrations	5.1	2.2	10.8	5.6
-Tax credit	3.1		6.3	
European Union	1.0	1.0	2.2	2.6
-Framework program	0.7		1.1	
Total	7.8	6.4	16.5	15.4

Looking at table 5.2, the differences in the percentage of firms reporting the receipt of support from the different government levels between the CIS 4 and the CIS 6 are considerable. For one the overall percentage decreased from 7.8 to 6.4% for the full sample and relatively less so for the innovative sample where it decreases from 16.5 to 15.4%. At the same time a substantially smaller proportion of the surveyed firms have replied to this question set in the first place, 15,303 out of 16,008 for the CIS 4 compared to 11,437 out of 13,856 for the CIS 6. For those that do respond the proportion of firms reporting support from 'central government' has decreased. This is expected since the firms receiving support 'from devolved administration' only should have classified themselves in the CIS 6 now as in receipt of support from 'local or regional authorities' instead of as in the CIS 4 classifying themselves in receipt of support from the 'central government or devolved administration'. However this observation also holds for England albeit to a lesser degree where the group receiving support from 'devolved administrations' should at best include only a few enterprises[262] and thus this decrease at least in part may have other reasons. At the same time the proportion of all firms in the survey reporting the receipt of support from 'local or regional authorities' for Scotland, Wales and Northern Ireland has fallen. Though for the innovative sample the 'local or regional authorities' support has increased for all non-English regions but has also somewhat increased for England. The weighted proportion of firms in receipt of EU support has not changed for the full sample among the CIS 4 and the CIS 6 but has increased somewhat for the non-English regions for the innovative sample. These comparisons are affected by the different response rates across the surveys as well as the different sample of firms understood to be innovation active according to CIS 6 definition in the CIS 4 and the CIS 6 since in the CIS 4 this definition has been applied retrospectively (also see table 2.26 page 71 middle).

The decrease in the weighted proportion of respondents that report to have received 'central government' support is also surprising in light of an increasing number of enterprises that have successfully claimed a tax credit. In fact the proportion of firms receiving the tax credit alone appears larger than the proportion of enterprises that report the receipt of 'central government' support in the CIS 6. The figures from HMRC show that the number of firms receiving an R&D tax credit has increased from 5,950 for tax year 2002-2003 to 6,570 for tax year 2006-2007. The first figure is in line with the information provided in the CIS 4. Using a back of the envelope calculation the 3% reporting to have received the R&D

[262] It is possible that firms which according to CIS are located in England have received support by devolved administrations. This is because the regional information stems from the where the head office of the reporting unit is located and not necessarily where individual plants are located which may qualify them for support from devolved administrations.

tax credit according to the CIS4, translated one to one to companies[263] where the CIS represents 170,000 reporting units from the IDBR which do not represent all reporting units in the UK, suggests that around 5,100 of these claimed a tax credit, which compares to the aforementioned 5,950. Thus while eligibility of the R&D tax credit has not changed and the number of its recipients increased the 'central government support' figures for CIS 6 has decreased even below the percentage of firms that previously reported to have received the tax credit.

There are several reasons why a single indicator variable for the receipt of public support is used despite the availability of information about three different levels of public support. Firstly as many firms receive several types of support, to identify the effects of individual policies would mean losing a lot of observations as well as ignoring complementary effects of policy. Furthermore the surveys do not provide information about what support programs exactly the firms participated in. As discussed the subcategories are no longer identical in the CIS 4 and the CIS 6, where previously central government support was contained together with devolved administration support this has now fallen under the region support subcategory. Most importantly proportions reporting support from different levels of government vary considerably while the overall proportions of firms receiving support of any type are more comparable. Statistically the different types of support show a great deal of overlap. Following Clausen (2007) a tetra-choric factor analysis of the three support variables has identified a single factor as chosen by the Kaiser criterion that explains 79% for the CIS 4 and 70% for the CIS 6 of the combined variance of the support variables. Thus also based on this result proceeding with a single variable for the receipt of public support is sensible.

The table of supported firms by sizeband (table 5.3) indicates a greater proportion of larger firms receive public support, though this effect disappears once the firm has more than 100 employees. When only looking at the innovative sample, a smaller proportion of larger firms and very small firms receive public support. The support by industry types (table 6.4) also varies largely and is mostly in line with

[263] Though these are reporting units thus several of them may actually make up a company, so the computed figure has to be discounted.

the likehood of innovating by industry as observed in the previous chapter, that is a larger proportion of firms in the 'manufacturing of electrical and optical equipments' industries as well 'as computer and related activities' industries receive support.

Table 5.3, Weighted % of firms in receipt of government support by sizeband

	CIS4	CIS6	CIS4	CIS6
	Whole Sample		Innovation Active	
N	15303	11437	8236	5572
9-19	6.1	5.4	14.9	14.8
20-49	8.8	6.4	19.0	16.4
50-99	10.4	9.3	19.9	18.0
100-199	11.4	7.8	19.0	16.9
200-499	8.5	8.3	13.8	13.1
500+	9.8	9.5	12.9	13.4
Total	7.8	6.4	16.5	15.4

Table 5.4, Weighted % of firms in receipt of public support by industry groups

	CIS4	CIS6	CIS4	CIS6
	Whole Sample		Innovation Active	
N	15303	11437	8236	5572
Mfr of food, clothing, wood, paper, publish& print	9.1	8.4	17.2	15.7
Mfr of fuels, chemicals, plastic metals& minerals	15.0	13.3	26.4	23.2
Mfr of electrical and optical equipments	23.3	22.1	35.1	34.2
Mfr of transport equipments	15.1	18.5	29.7	30.9
Mfr not elsewhere classified (including mining & quarrying, electricity)	12.1	11.6	19.2	19.6
Construction	4.8	3.6	10.8	8.3
Wholesale trade (including cars & bikes)	4.6	4.3	7.6	9.4
Retail trade (excluding cars & bikes)	3.9	4.8	5.2	8.3
Hotels & restaurants	3.7	2.2	8.0	7.5
Transport, storage & communication	5.6	3.4	13.8	9.0
Financial intermediation	2.6	2.3	4.7	4.3
Real estate, renting & other business (including gas & water supply)	10.3	7.3	16.2	14.9
Total	7.8	6.4	16.5	15.4

Table 5.5, Innovative performance by public support

	support	CIS4	CIS6	CIS4	CIS5
		Whole Sample		Innovation Active	
Innovators (%)	no	27.6	27.6	66.1	66.9
	yes	68.6	66.3	82.8	83.3
Product innovators (%)	no	22.8	23.9	53.2	58.2
	yes	61.5	61.6	74.0	74.8
Process innovators (%)	no	13.8	12.5	36.3	32.2
	yes	40.1	38.4	52.9	49.8
Goods innovators (%)	no	13.4	14.4	33.3	34.7
	yes	46.2	44.4	57.3	56.2
Service innovators (%)	no	15.6	17.4	33.9	41.0
	yes	34.3	43.8	38.3	48.7
Cooperative Innovators (%)	no	7.1	11.7	18.0	28.2
	yes	20.8	33.4	27.5	38.4
Wider innovators (%)	no	29.3	28.8	72.6	76.3
	yes	65.9	63.2	78.3	80.7
Wider intensity	no	26.8	1.2	-0.02	-0.01
	yes	62.5	5.3	0.07	0.09
Design (%)	no		1.2		3.0
	yes		5.3		8.9
Trademark (%)	no		5.3		11.4
	yes		16.3		21.3
Patent (%)	no		2.7		7.0
	yes		12.6		19.7
Copyright (%)	no		5.5		10.3
	yes		18.3		24.7
R&D performers (%)	no	19.7	22.5	41.5	45.3
	yes	58.2	60.4	68.1	74.0

For the whole sample the weighted proportion of firms that carry out R&D is roughly three times larger for those firms receiving public support (table 6.5). Whereas the proportion of firms that innovate is about 2.5 times higher among those firms receiving public support. About twice the proportion of firms that receive public support carry out wider forms of innovation. Similar trends are observed across the other innovative activities with effects being as expected less pronounced when only looking at the innovative sub-sample. This table (6.5) may lead one to conclude that indeed government support is effective. However as previously argued this ignores the selection issue. The government is likely to support firms which have better innovative performance and thus these observations may simply confirm this selection bias. Hence while these tables may be suggestive of the effectiveness of support the ensuing analysis is required to be able to draw conclusions about this matter.

The measures of innovative performance that have just been presented are the ones that are used to establish the treatment effect. Previous studies, mostly due data availability have focused on R&D intensity and sometimes patents as the treatment variable. R&D itself is not a direct measure of innovativeness but a proxy and in any case only an input to innovation. So it is not clear to what extent government stimulated R&D actually leads to innovative outputs the same way that "standard" R&D leads to innovative outputs. As argued in the data chapter broader measures of innovative activity and outputs should be used. Though R&D spending due to its wide availability is still useful and also as confirmed in the previous chapter itself is an important driver of innovation. The stimulated R&D may however not be as effective in generating additional outputs. The CIS fortunately beyond just information about R&D also includes information on whether firms carried out wider innovation or introduced product and process innovation which are hence included in the analysis to see the impact of government support on these outcome variables.

5.6. Results

Table 5.6, Descriptive statistics non-supported and supported firms, CIS 4

	without support		with support			
N	6810		1343			
variables	Mean	std dev	Mean	std dev	mean difference	p-value
log(employment)	4.39	1.60	4.27	1.43	-0.13	0.004
SME	0.83	0.37	0.88	0.32	0.05	0.000
Exporter	0.41	0.49	0.61	0.49	0.20	0.000
Foreign ownership	0.14	0.35	0.11	0.32	-0.03	0.003
New entrant	0.14	0.35	0.16	0.37	0.01	0.185
Absorptive capacity	-0.06	0.86	0.32	0.77	0.38	0.000
Cooperation	0.21	0.41	0.43	0.50	0.22	0.000
North East	0.05	0.21	0.09	0.28	0.04	0.000
North West	0.09	0.29	0.08	0.28	-0.01	0.200
Yorkshire& Humber	0.08	0.27	0.08	0.27	0.00	0.572
East Midlands	0.08	0.28	0.06	0.24	-0.02	0.002
West Midlands	0.09	0.28	0.09	0.29	0.00	0.565
Eastern England	0.09	0.29	0.06	0.24	-0.03	0.000
London	0.12	0.32	0.04	0.20	-0.08	0.000
South East England	0.12	0.33	0.08	0.28	-0.04	0.000
South West England	0.08	0.28	0.07	0.25	-0.02	0.010
Wales	0.05	0.22	0.12	0.33	0.07	0.000
Scotland	0.07	0.25	0.09	0.29	0.02	0.004
Northern Ireland	0.07	0.25	0.13	0.34	0.06	0.000
Innovators	0.66	0.47	0.83	0.38	0.17	0.000
Product Innovators	0.53	0.50	0.74	0.44	0.21	0.000
Process Innovators	0.36	0.48	0.53	0.50	0.17	0.000
Goods Innovators	0.33	0.47	0.57	0.49	0.24	0.000
Service Innovators	0.34	0.47	0.38	0.49	0.04	0.004
Cooperative Innovation	0.18	0.38	0.28	0.45	0.10	0.000
Wider Innovators	0.72	0.45	0.78	0.41	0.06	0.000
Wider Innovation Intensity	-0.02	0.43	0.08	0.45	0.09	0.000
R&D performers	0.41	0.49	0.68	0.47	0.27	0.000
R&D spending / sales	0.95	4.48	3.96	10.76	3.01	0.000
R&D spending / employee	714.15	3384.43	3191.21	8636.97	2477.06	0.000

Table 5.7, Descriptive statistics non-supported and supported firms, CIS 6

	without support		with support			
N	3981		780			
variables	Mean	std dev	Mean	std dev	mean difference	p-value
log(employment)	4.38	1.57	4.26	1.44	-0.12	0.031
SME	0.84	0.36	0.88	0.32	0.04	0.002
Exporter	0.44	0.50	0.68	0.47	0.23	0.000
Foreign ownership	0.17	0.37	0.16	0.36	-0.01	0.454
New entrant	0.08	0.27	0.08	0.27	0.00	0.749
Absorptive capacity	-0.06	0.82	0.30	0.75	0.36	0.000
Cooperation	0.72	0.45	0.85	0.36	0.13	0.000
North East	0.06	0.24	0.09	0.29	0.03	0.011
North West	0.09	0.28	0.08	0.26	-0.01	0.214
Yorkshire& Humber	0.09	0.29	0.06	0.24	-0.03	0.006
East Midlands	0.09	0.29	0.07	0.25	-0.02	0.015
West Midlands	0.09	0.29	0.09	0.29	0.00	0.764
Eastern England	0.09	0.29	0.07	0.25	-0.03	0.007
London	0.10	0.30	0.03	0.18	-0.07	0.000
South East England	0.11	0.31	0.05	0.21	-0.07	0.000
South West England	0.09	0.28	0.08	0.28	0.00	0.777
Wales	0.06	0.23	0.13	0.33	0.07	0.000
Scotland	0.08	0.27	0.14	0.35	0.07	0.000
Northern Ireland	0.05	0.22	0.11	0.31	0.06	0.000
Innovators	0.73	0.44	0.87	0.34	0.14	0.000
Product Innovators	0.64	0.48	0.78	0.42	0.14	0.000
Process Innovators	0.36	0.48	0.53	0.50	0.17	0.000
Goods Innovators	0.38	0.49	0.58	0.49	0.20	0.000
Service Innovators	0.45	0.50	0.51	0.50	0.06	0.004
Cooperative Innovation	0.31	0.46	0.40	0.49	0.10	0.000
Wider Innovators	0.75	0.43	0.81	0.40	0.06	0.000
Wider Innovation Intensity	-0.01	0.44	0.09	0.46	0.10	0.000
Design	0.03	0.18	0.09	0.29	0.06	0.000
Trademark	0.12	0.32	0.22	0.41	0.10	0.000
Patent	0.08	0.26	0.20	0.40	0.13	0.000
Copyright	0.11	0.31	0.26	0.44	0.15	0.000
R&D performers	0.48	0.50	0.75	0.43	0.27	0.000
R&D spending / sales	1.03	4.49	4.08	10.36	3.05	0.000
R&D spending / employee	1020.13	4534.78	3677.36	9785.50	2657.23	0.000

The sample as noted is restricted to firms considered innovation active under the CIS 6 definition and those that have all exogenous and endogenous variables relevant to the analysis available. This leaves 1343 treated firms and 6810 potential controls for the CIS 4 and 780 treated firms and 3981 potential controls for the CIS 6. The large sample sizes available means the data is ideal for matching as this improves the likehood of finding matches that are very close in terms of the propensity score. Looking at the variable means of the supported versus those of the remaining firms in table 6.6 and table 6.7 there exists a statistically significant difference for all of the exogenous variables except for new entrants for the CIS 4 and new entrants and foreign ownership and to some degree employment size for the CIS 6 as well as some of the regional dummies for both surveys. For this reason the use of propensity score matching to overcome the selection problem is necessary. As a result it should be possible to assert whether observed differences in dependent variables are due to the receipt of support or a result of sample selection bias

The probability model for the receipt of public support is the propensity score model used for matching treated with untreated observations. Table 6.8 shows the estimation results of the probit model explaining the receipt of public financial support for innovation. Let's looks at each of the coefficients sign and significance in turn.

Table 5.8, Probit estimation Pr(public support), mfx (at the means)

	CIS 4	CIS 5	CIS 4		CIS 5	
Observations	8,153	4,761				
variables	Means		dF/dx	std.error	dF/dx	std.error
Public support	0.17	0.16				
log(employment)	4.37	4.36	-0.002	0.003	0.001	0.005
SME	0.84	0.85	0.021	0.013	0.016	0.018
Exporter	0.45	0.48	0.038***	0.009	0.077***	0.011
Foreign owned	0.14	0.16	-0.059***	0.009	-0.054***	0.011
New firm	0.15	0.08	0.029**	0.012	0.014	0.020
Absorptive capacity	0.00	0.00	0.044***	0.005	0.051***	0.006
Cooperation	0.25	0.74	0.123***	0.011	0.054***	0.011
North East	0.05	0.07	0.225***	0.036	0.214***	0.046
North West	0.09	0.09	0.098***	0.027	0.122***	0.039
Yorkshire& Humber	0.08	0.09	0.095***	0.028	0.085**	0.037
East Midlands	0.08	0.09	0.057**	0.026	0.066*	0.035
West Midlands	0.09	0.09	0.102***	0.027	0.126***	0.038
Eastern England	0.09	0.09	0.032	0.023	0.072**	0.035
South East England	0.12	0.10	0.048**	0.023	0.009	0.030
South West England	0.08	0.09	0.072***	0.026	0.121***	0.039
Wales	0.07	0.07	0.275***	0.035	0.307***	0.048
Scotland	0.07	0.09	0.174***	0.031	0.233***	0.043
Northern Ireland	0.08	0.06	0.246***	0.033	0.277***	0.047
Mining and quarrying	0.01	0.01	0.061	0.048	0.090	0.082
Mfr of food, clothing, wood, paper, publish & print	0.10	0.09	0.057***	0.021	0.014	0.025
Mfr of fuels, chemicals, plastic metals & minerals	0.14	0.12	0.128***	0.023	0.077***	0.028
Mfr of electrical and optical equipments	0.06	0.07	0.203***	0.031	0.144***	0.037
Mfr of transport equipments	0.03	0.03	0.159***	0.036	0.172***	0.046
Mfr not elsewhere classified	0.04	0.04	0.081***	0.030	0.054	0.035
Electricity, gas & water supply	0.00	0.01	-0.010	0.101	0.135	0.103
Construction	0.07	0.06	-0.000	0.020	-0.024	0.026
Wholesale trade (incl cars & bikes)	0.08	0.08	-0.023	0.018	-0.018	0.024
Retail trade (excl cars & bikes)	0.06	0.05	-0.067***	0.015	-0.012	0.028
Hotels & restaurants	0.04	0.05	-0.031	0.022	-0.030	0.028
Transport, storage	0.05	0.06	0.060**	0.027	-0.029	0.026
Post & Courier activities	0.01	0.01	-0.060*	0.034	-0.028	0.053
Telecommunications	0.02	0.01	0.065	0.042	0.080	0.062
Financial intermediation	0.05	0.04	-0.070***	0.016	-0.076***	0.022
Real estate	0.02	0.04	0.083**	0.036	0.086**	0.039
Renting of Machinery and Equipment	0.02	0.02	-0.016	0.033	-0.021	0.036
Computer and Related Activities	0.04	0.06	0.188***	0.034	0.118***	0.037
Architectural and engineering activities& related technical consult	0.03	0.05	0.073**	0.030	0.031	0.031
Technical testing and analysis	0.01	0.01	0.118**	0.047	0.001	0.046
p - value of Chi-squared			0.0000		0.0000	
McFadden R2			0.155		0.139	

Increased employment does not significantly increase the likehood of receipt of public support. Some of the public support is directed specifically at SMEs, the coefficient of the dummy capturing whether a firm is an SME while positive is not significant though. Both results are contrary to previous findings of the literature for other countries then the UK namely that public support is biased towards larger firms (Almus and Czarnitzki, 2003; Aerts and Czarnitzki, 2004; Blanes and Busom, 2004; Duguet, 2004; Aerts and Schmidt, 2006). Given the positive relationship between the absorptive capacity measure and firm size (table 3.86, page 183) it is thus possible that part of the previous findings in the literature are the result of miss-specified models. That is their coefficient on size was significant because their measure of past innovative activities was biased towards R&D activities.

In line with expectations and previous findings (Almus and Czarnitzki, 2003; Aerts and Czarnitzki, 2004; Heijs and Herrera, 2004; Kaiser, 2004; Clausen, 2007) exporters are more likely to receive public support, the rational here is that they are more competitive and thus more likely to apply for innovative support. This effect is significant though the marginal effect is around twice the size for the CIS 6 compared to the CIS 4 while mean values at which they were computed are similar.

Firms owned by a foreign company according to the model are less likely to be in receipt of public support, this is in line with previous findings (Blanes and Busom, 2004; Aerts and Czarnitzki, 2004; Heijs and Herrera, 2004; Hussinger, 2008) and suggests that innovation policy is directed towards domestic firm support or that foreign firms carry out most of their R&D in their home-country. In any case public support for innovation is not as extensively used by foreign firms as it is by domestic firms. This suggests that there is room for improvement in supporting and thus attracting foreign R&D activities.

Start-ups are more likely to be in receipt of public support, some of the public support being directed at them due to their role in increasing employment and generating radical innovations. However this effect is no longer significant for the CIS 6, though here this information is somewhat different in that it represents only new entrants established during the survey period whereas in CIS 4 this includes new entrants up to two years prior to the survey period. This sort of finding is not directly comparable to previous research where the specifications used an age variable or a transformation thereof, showing a positive influence of being older on the likehood of receiving support (Busom, 2000; Czarnitzki and Hussinger, 2004).

Cooperating increases the likehood of receiving public support. This is in line with government support targeting cooperative arrangements that are expected to stimulate sharing of knowledge. Previously only Heijs and Herrera (2004) look for and identify a positive effect of cooperating on the receipt of support by firms in Spain and in a later paper Herrera and Nieto (2008) find no significant relationship with the receipt of public support.

As postulated the absorptive capacity measure has a positive impact on the likelihood of receiving public support. The absorptive capacity as argued proxies for past innovativeness but also reflects expertise within the firm with regard to making applications. Past innovativeness is also a potential selection criterion for government support "picking winners". Previous research has confirmed that existence of R&D departments and other indicators of past R&D activities (or patenting) have a positive impact on the likehood of receiving public support for innovation (Almus and Czarnitzki, 2003; Blanes and Busom, 2004; Clausen, 2007).

Being part of an enterprise group also had a positive effect on the likehood of receiving public support, though the effect was not significant and it was thus dropped from the specification. Otherwise the observations from Northern Ireland would have had to be discarded since this information for the CIS 6 can only be obtained from the ARD which does not cover Northern Ireland.

Most of the regional dummies are significant, the baseline group is London. Firms in the North East, Wales, Scotland and Northern Ireland are more likely to be in receipt of public support which confirms that differences exits across regions in terms of likehood of being in receipt of support for innovation.

About half of the industry dummies are significant, potentially explaining differing technological opportunities as well as reflecting support directed towards specific industries. The ‘other business activities’ division acted as the baseline group. From the results in the previous chapter it is expected that particularly ‘manufacturing of electrical and optical equipments’ and ‘computer and related activities’ should due to their increased technological opportunities apply more often for public support and these expectations are confirmed with their coefficients being positive and statistically significant. UK government support particularly targets the ‘manufacturing of fuels, chemicals, plastic metals and minerals’ sector, the results show that these have a higher likehood of being in receipt of government support then most of the other industries. A joint test of the industry dummies confirmed them to be highly significant.

Comparing these results with the government objectives of public support for innovation it is observed that while firms that are export oriented and have above average absorptive capacity are more likely to receive funds, being an SME does at least not make it less likely to be in receipt of support and being a start-up and/or cooperating makes it more likely to obtain funding. The results rule out that larger firms do have an advantage in obtaining government support where most of the previous research which was undertaken for countries other than the UK found that larger firms were at an advantage (for example Blanes and Busom, 2004; Czarnitzki and Hussinger 2004; Duguet, 2004; Aerts and Schmidt, 2006; Clausen, 2007). The funding probability model thus suggests that the likelihood of receiving support is in line with government policy objectives with respect to start-up support and support of cooperation but the support of SMEs may need improvement.

Next the results of creating a control group are presented. Due to the common support restriction 32 and 27 observations of supported firms for the CIS 4 and CIS 6 respectively had to be removed. This is 2.4% / 3.5% of all treated observations and thus allows to conclude that the common support restriction is fairly well justified. The remaining 1311 and 753 supported enterprises were matched to 1001 and 583 controls respectively in the one to one matching procedure with replacement.

Table 5.9, Descriptive Statistics controls and supported firms, CIS 4[264]

observations		1001		1311			
variables		Mean	std dev	Mean	std dev	mean difference	p value
log(employment)		4.28	1.49	4.29	1.44	0.01	0.941
SME		0.88	0.33	0.88	0.33	0.00	0.854
Exporter		0.55	0.50	0.61	0.49	0.06	0.029
Foreign ownership		0.12	0.33	0.12	0.32	-0.01	0.621
New entrant		0.16	0.37	0.16	0.36	-0.01	0.759
Absorptive capacity		0.19	0.81	0.30	0.76	0.11	0.011
Cooperation		0.38	0.48	0.42	0.49	0.05	0.097
North East England		0.09	0.29	0.08	0.28	-0.01	0.645
North West England		0.09	0.29	0.09	0.28	-0.01	0.671
Yorkshire & the Humber		0.07	0.26	0.08	0.27	0.01	0.704
East Midlands		0.06	0.25	0.06	0.24	0.00	0.860
West Midlands		0.09	0.28	0.10	0.29	0.01	0.691
Eastern England		0.07	0.25	0.06	0.24	0.00	0.848
London		0.05	0.22	0.04	0.20	-0.01	0.532
South East England		0.10	0.31	0.09	0.28	-0.02	0.246
South West England		0.07	0.25	0.07	0.25	0.00	0.989
Wales		0.10	0.31	0.12	0.32	0.01	0.452
Scotland		0.10	0.30	0.09	0.29	-0.01	0.582
Northern Ireland		0.09	0.29	0.12	0.33	0.03	0.107
Innovators		0.71	0.45	0.83	0.38	0.12	0.000
Product Innovators		0.60	0.49	0.74	0.44	0.13	0.000
Process Innovators		0.37	0.48	0.53	0.50	0.15	0.000
Goods Innovators		0.44	0.50	0.57	0.50	0.14	0.000
Service Innovators		0.34	0.47	0.38	0.49	0.04	0.132
Cooperative Innovation		0.20	0.40	0.27	0.45	0.08	0.002
Wider Innovators		0.73	0.45	0.78	0.41	0.06	0.018
Wider Innovation Intensity		-0.01	0.43	0.07	0.45	0.09	0.001
R&D performers		0.49	0.50	0.68	0.47	0.19	0.000
R&D spending / sales		1.33	5.24	3.90	10.51	2.57	0.000
R&D spending / employee		974.01	3216.94	3179.97	8647.51	2205.96	0.000
Finance Barriers		0.10	1.00	0.24	0.92	0.14	0.007
Knowledge Barriers		0.05	0.83	0.19	0.77	0.14	0.002
	N	615			876		
R&D spending / sales		2.88	7.91	5.78	12.42	2.91	0.000
R&D spending / employee		2045.67	4581.73	4637.34	10084.72	2591.67	0.000

[264] Kernel densities of estimated propensity score before and after matching can be found in the Appendix (5.8).

Table 5.10, Descriptive Statistics controls and supported firms, CIS 6

observations	583		753			
variables	Mean	std dev	Mean	std dev	mean difference	p value
log(employment)	4.34	1.49	4.25	1.44	-0.09	0.372
SME	0.86	0.35	0.88	0.32	0.02	0.416
Exporter	0.63	0.48	0.66	0.47	0.04	0.269
Foreign ownership	0.17	0.38	0.16	0.37	-0.01	0.694
New entrant	0.08	0.28	0.08	0.27	0.00	0.878
Absorptive capacity	0.22	0.79	0.27	0.73	0.04	0.431
Cooperation	0.83	0.38	0.84	0.36	0.01	0.621
North East England	0.09	0.28	0.09	0.29	0.01	0.775
North West England	0.08	0.27	0.08	0.27	0.00	0.853
Yorkshire& the Humber	0.08	0.27	0.07	0.25	-0.01	0.507
East Midlands	0.08	0.26	0.07	0.25	-0.01	0.674
West Midlands	0.11	0.31	0.10	0.30	-0.01	0.710
Eastern England	0.08	0.27	0.07	0.25	-0.01	0.609
London	0.04	0.20	0.04	0.19	-0.01	0.611
South East England	0.05	0.23	0.05	0.21	-0.01	0.652
South West England	0.07	0.25	0.08	0.28	0.02	0.400
Wales	0.11	0.32	0.12	0.32	0.01	0.729
Scotland	0.13	0.33	0.14	0.35	0.02	0.528
Northern Ireland	0.09	0.29	0.10	0.30	0.01	0.669
Innovators	0.77	0.42	0.87	0.34	0.10	0.000
Product Innovators	0.68	0.47	0.77	0.42	0.09	0.003
Process Innovators	0.40	0.49	0.53	0.50	0.13	0.000
Goods Innovators	0.49	0.50	0.58	0.49	0.09	0.008
Service Innovators	0.43	0.50	0.49	0.50	0.06	0.094
Cooperative Innovation	0.34	0.48	0.39	0.49	0.05	0.155
Wider Innovators	0.76	0.43	0.80	0.40	0.04	0.198
Wider Innovation Intensity	0.02	0.45	0.08	0.46	0.06	0.048
Design	0.06	0.23	0.09	0.29	0.04	0.064
Trademark	0.15	0.36	0.21	0.41	0.06	0.023
Patent	0.13	0.33	0.20	0.40	0.08	0.005
Copyright	0.14	0.35	0.25	0.44	0.11	0.000
R&D performers	0.59	0.49	0.75	0.44	0.15	0.000
R&D spending / sales	2.00	6.83	3.98	10.30	1.98	0.003
R&D spending / employee	1982.53	7106.96	3645.63	9833.398	1663.10	0.010
Finance Barriers	0.13	0.96	0.17	0.88	0.04	0.589
Knowledge Barriers	0.11	0.78	0.17	0.75	0.06	0.249

N	396		551			
R&D spending / sales	3.16	8.60	5.34	11.62	2.17	0.019
R&D spending / employee	2945.55	8158.65	4830.60	10860.94	1885.05	0.030

Tables 5.9 and 5.10 show the distribution of the variables between the supported firms and the matched controls. They indicate that the matching was not perfect. There still are some significant differences for the exogenous variables among the controls and the treated group at the 10% significance level for the CIS 4, though none for the CIS 6. These include the propensity to export, the absorptive capacity and cooperation, however at the 1% significance level the hypothesis that these variables are equal for the treated firms and their controls cannot be rejected. On the other hand the differences among most of the performance measures are highly significant and these significant differences now can be attributed to the government support based on the conditional independence assumption. Only for service innovations for the CIS 4 and for cooperative innovation as well as wider innovation for the CIS 6 are the effects not significant at the 10% level. Re-estimating the matching equation for the matched sample also indicates that the joint significance of the variables can be rejected at 1%. Therefore the matching has balanced the samples fairly well and indicates that the government financial support towards innovation is effective.

The weighted treatment effects (table 5.11) are all positive and most are significant as shown in the mean comparisons previously (tables 5.9 and 5.10). They are very similar across the surveys, with notable differences only in the effect on the likehood of introducing wider innovations and particularly for R&D intensity which are both lower for the CIS 6. The results indicate that government support stimulates the likehood of innovating by 9 to 10% and the likehood of carrying out R&D by 13 to 16%. Firms in support were also more likely to report to have applied for copyrights, design registrations, trademarks and patents. Similarly the R&D spending intensities have increased. The bottom of the table shows the results of the matching carried out only for firms that reported positive R&D spending. These results are presented because all of the reviewed studies apart from Aerts and Czarnitzki (2004) and Gonzalez and Pazo (2008) have used for their analysis only those firms that reported positive R&D spending, hence their results are more comparable with these figures. The increase in R&D spending by 2.9% (CIS4) and 1.8% (CIS6) relative to total sales is very similar to the results of for instance Almus and Czarnitzki (2003) who find an increased in R&D intensity of 3.94%, Aerts and Czarnitzki (2004) of 2.47% or Aerts and Schmidt (2006) who find the treatment effect to be a 5.33% increase in R&D intensity, as well as Hussinger (2008) and Herrera and Nieto (2008) who both find them to be in the order of 2%. Generally speaking the treatment effects are larger for the CIS 4 then for the CIS 6.

Table 5.11, Weighted treatment effects (as % except R&D spending / employee)

	CIS4	CIS6
N	1311	753
Innovators	8.5	9.8
Product innovators	10.6	8.1
Process innovators	12.4	12.5
Goods Innovators	9.0	7.6
Service Innovators	4.7	5.7
Cooperative Innovators	5.2	4.1
Wider Innovators	6.0	3.2
Wider Intensity	8.2	6.1
Design		3.3
Trademark		6.1
Patent		7.2
Copyright		9.3
R&D performers	15.8	12.6
R&D spending / sales	2.4	1.7
R&D spending / employee	2055.5	1388.8
N	876	551
R&D spending / sales	2.9	1.8
R&D spending / employee	2572.1	1777.7

The regression after matching is presented in tables 5.12 and 5.13. This is to serve as a robustness check since it accounts for any remaining difference in the distribution of the variables among the treated and controls. According to the results the likehood of performing R&D increases by around 37.0% compared to the estimated treatment effect from simple propensity score matching without regression of 15.8% for the CIS4. Once only firms that have carried out R&D are considered the effect of public support according to the regression after matching is that R&D spending per employee increases from on average for those that carry out R&D of log (£ 4027) by 0.574 to log (£7135) in other words the R&D spending per employee increases by £3108. This is again somewhat larger than the result suggested from simple propensity score matching which was calculated to be £2572. Both of these effects are smaller than the effects when including the public support variable in the R&D model for the whole sample and thus confirm that when not accounting for the endogeneity of public support the estimates are biased. These findings suggest that the previously obtained figures (table 6.11) are if anything downward biased, and thus also based on the regression after matching approach the effectiveness of public support in stimulating both the likehood of carrying out R&D and spending on R&D is confirmed.

Table 5.12, Heckman step 1 R&D participation (0/1)

Sample	CIS4	CIS 4
	Full Sample	Matched Sample
Observations	13920	2059
log(employment)	0.137***	0.077**
	(0.013)	(0.035)
Wales	-0.044	-0.129
	(0.070)	(0.089)
Scotland	-0.068	-0.171*
	(0.073)	(0.097)
Foreign ownership	-0.173**	-0.188*
	(0.067)	(0.097)
log(Herfindahl)	0.050	-0.001
	(0.031)	(0.050)
Absorptive capacity	0.754***	0.194***
	(0.034)	(0.047)
Absorptive capacity^2	-0.338***	-0.119***
	(0.026)	(0.038)
Appropriation	0.680***	0.452***
	(0.045)	(0.048)
Appropriation^2	-0.213***	-0.183***
	(0.024)	(0.032)
public support	0.464***	0.370***
	(0.057)	(0.060)
p - Wald joint sig. divisions	0.000	missing[265]

[265] Could not be computed due to insufficient rank condition, at least one of the observations is nonzero for only one strata in the survey.

Table 5.13, Heckman step 2 - log (R&D spending/employment)

Sample	CIS4	CIS 4
	Full Sample	Matched Sample
Observations	3934	1230
Cooperation	0.205**	0.153
	(0.085)	(0.098)
Wales	-0.113	-0.176
	(0.135)	(0.150)
Scotland	-0.151	-0.349**
	(0.155)	(0.171)
Foreign Ownership	-0.009	0.071
	(0.130)	(0.147)
log(Herfindhal)	0.134**	0.144*
	(0.059)	(0.082)
Absorptive capacity	0.910***	0.244**
	(0.155)	(0.122)
Absorptive capacity^2	-0.428***	-0.112
	(0.084)	(0.097)
Appropriation	1.566***	0.739***
	(0.110)	(0.123)
Appropriation^2	-0.421***	-0.142**
	(0.053)	(0.065)
public support	0.993***	0.574***
	(0.108)	(0.109)
p - Wald joint sig. - divisions	0.000	missing
p - Wald sig. - rho	0.000	0.002
p - Wald independent equations	0.000	missing
Log-likehood	-126653.240	-3523.466

5.7. Conclusion

This chapter has first outlined the rationales for government support to attempt to stimulate innovation. At the same time arguments were presented why government support may be ineffective. Next the factors identified in the literature that influence the likehood of receiving public support were presented. The recipients on theoretical grounds are thus not likely to be a random sample and therefore the effect of the government support on their innovative activities has to be estimated using an approach that accounts for sample selection. The following section then detailed the propensity score matching approach which allows the creation of a counterfactual sample compared to which differences in innovative performance can be attributed to the public support. The data section showed the distribution of the proportion of firms in receipt of public support across size, industry and region, it also showed the differences in the innovative performance between the supported and the remaining firms. This section also listed the variables to be used as regressors in a propensity score model explaining the likehood of receipt of public support and specifically justified the use of the absorptive capacity measure for this purpose. The next section first showed the differences in the means of these explanatory variables among the treated firms and the remaining sample of firms which confirmed that the treated sample is distinct from the rest and thus substantiated that accounting for sample selection through the propensity score model is necessary. The results of the propensity score model explaining the receipt of public support for innovation shows that larger firms are not at an advantage in attracting support. Nor are SMEs (at least not significantly), though start-ups and cooperating firms are more likely to be in receipt of public support (this effect has only been shown significant for the CIS 4 and not the CIS 6). Nevertheless exporters and firms with strong absorptive capacity in other words firms that are particularly competitive are more likely to be in receipt of government support. Since most of the present day support is not explicitly directed at firms with track records it is likely that this observation is thus an artefact of the persistence of innovative activities in firms that is the cumulativeness of technological capabilities. Those firms that carried out R&D in the past and have thus generated absorptive capacity are simply applying again for say tax credits towards their continued R&D activities and thus firms with larger absorptive capacity are more likely to be in receipt of support. There were also considerable regional effects explaining the likehood of receiving support, for instance firms in the devolved regions were more likely to be in receipt of support towards innovation. Foreign owned firms were also less likely not to be in receipt of public support. Based on this propensity score model a matched sample was created to compare its innovative performance with that of the treated sample. The results show that the UK financial support towards innovation has a positive impact on innovative performance indicating that public support is effective in stimulating innovative activities. Repeating the Heckman model (stage one of the previous chapter) for the matched sample of the CIS 4 also confirms the support to be effective. The size of the public support coefficients was less then when estimating the model for the full sample. This confirms that including it for the full sample leads to overestimating the effect of public support, due endogeneity of the support variable.

The main contribution of this chapter for to the literature was to provide direct evidence on the effectiveness of financial public support for innovation in the UK which is particularly interesting in light of the newly imposed tax credit. The finding that policy is effective when contrasted with the observation that R&D spending stayed fairly constant over time (Figure 1.1) suggests that without government intervention the result may have been that this sort of spending would have decreased further to the detriment of economic growth. This chapter further contributed by establishing the factors that explained the likehood of receipt the aforementioned support, again an empirical investigation not previously conducted for the UK. Unlike for most studies using the propensity score matching to investigate the effectiveness of public support, not only the effect for firms that carried out R&D could be established but also firms that were innovation active in general as these were available from the data. This hence further allowed to check and to confirm that government support stimulated firms into undertaking R&D. Lastly unlike in previous studies the effect of policy on other measures of innovative performance was also investigated and found to be positive. There were also two methodological contributions compared to the previous literature, firstly the use of the absorptive capacity measure generated in chapter 3 to predict the likehood of receipt of public support allowed to proxy for past innovative activity but without being biased towards R&D. The latter represents an imperfect proxy as it is more relevant and observable for manufacturing and larger firms. Admittedly this like in the previous chapter was also a forced choice since there is simply no information on the persistence of innovative activity. The second methodological contribution is the use of regression after matching to account for any remaining heterogeneity among treated and controls which again confirmed the stimulating effects of public policy for innovation.

5.8. Appendix – Kernel Density Estimates of Propensity Score

Figure 5.1, Kernel density of propensity score, CIS 4 - before matching

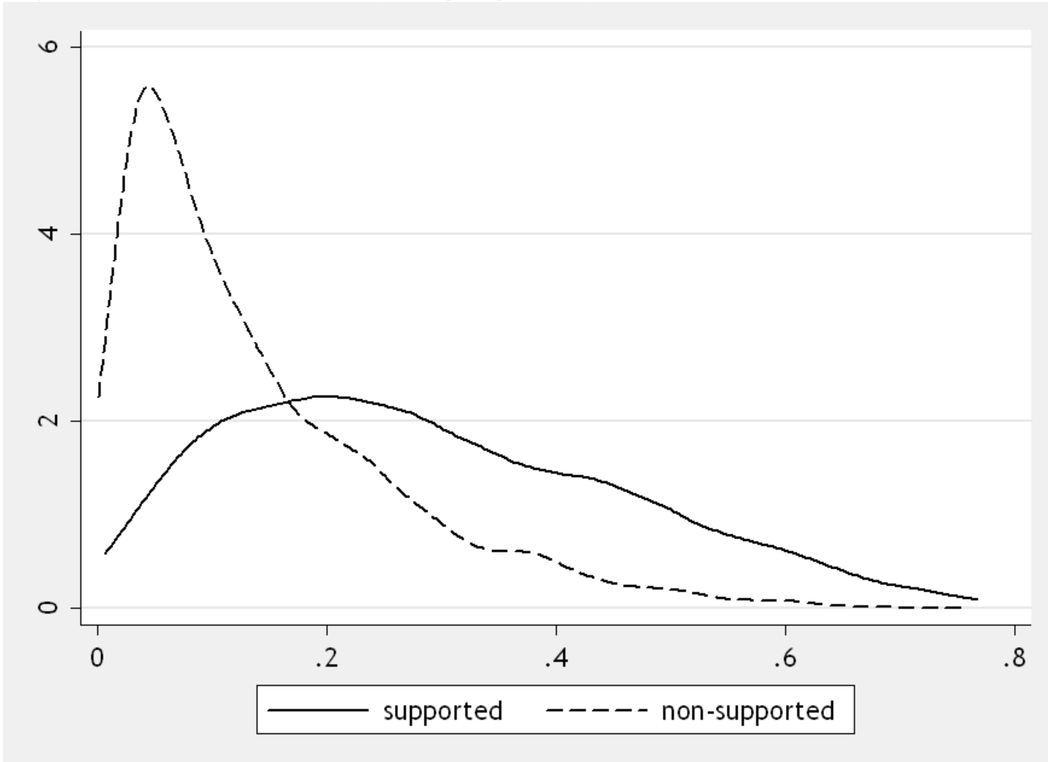


Figure 5.2, Kernel density of propensity score, CIS 6 - before matching

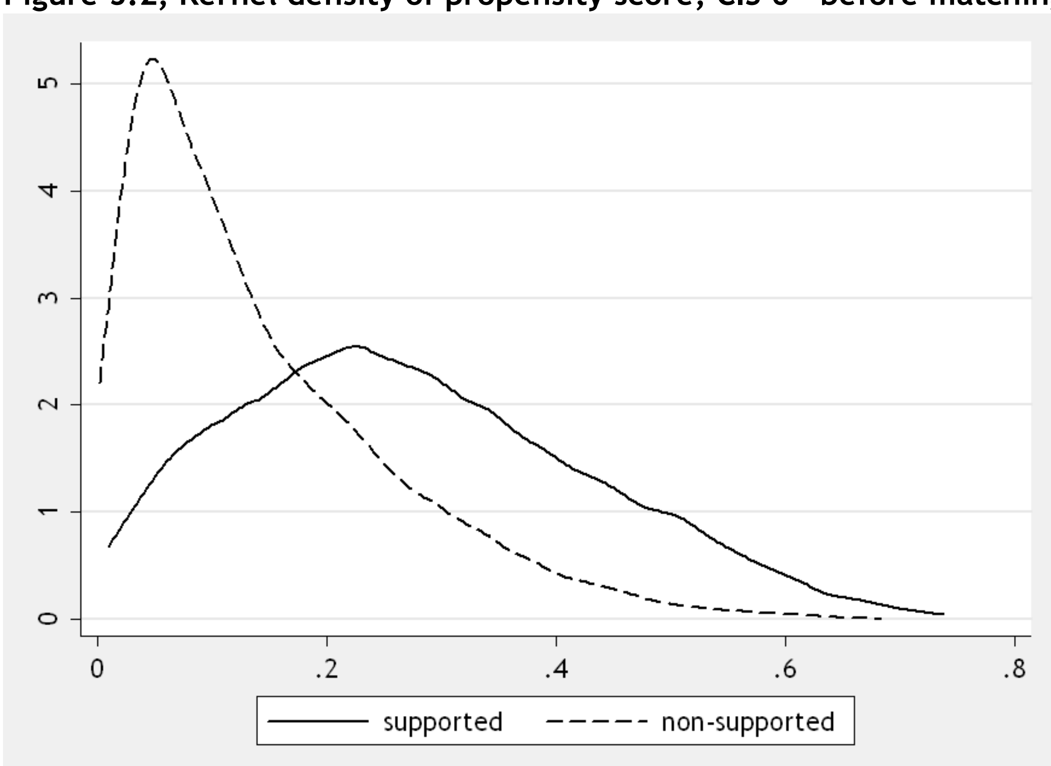


Figure 5.3, Kernel density of propensity score, CIS 4 – after matching

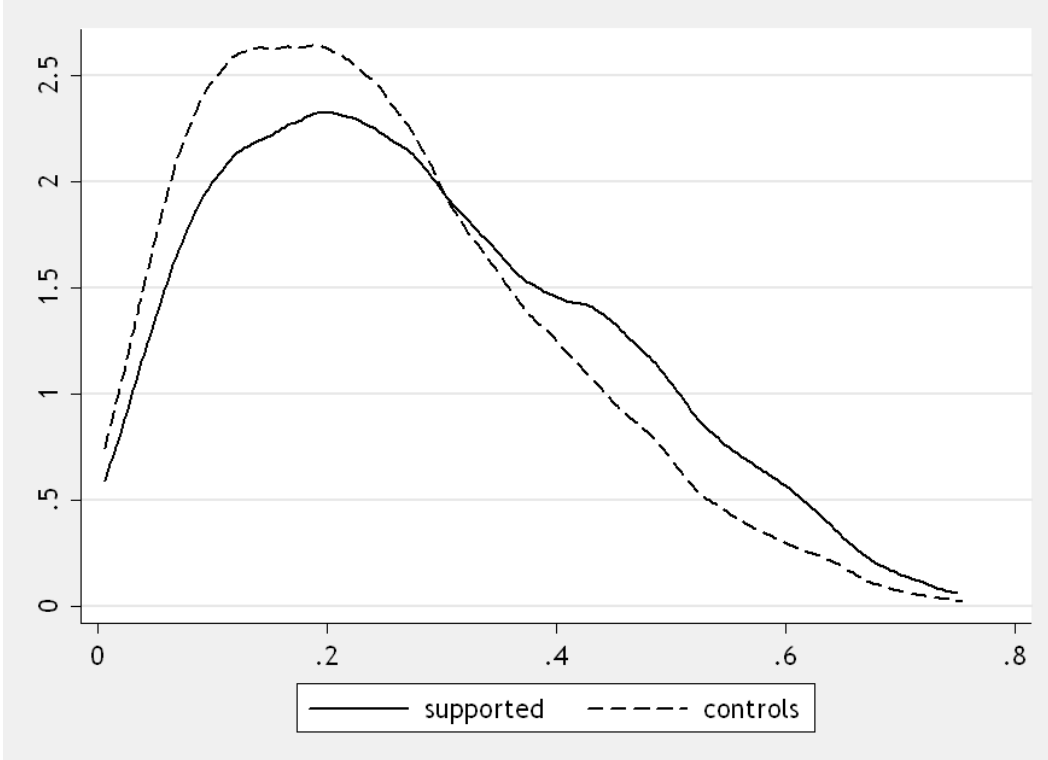
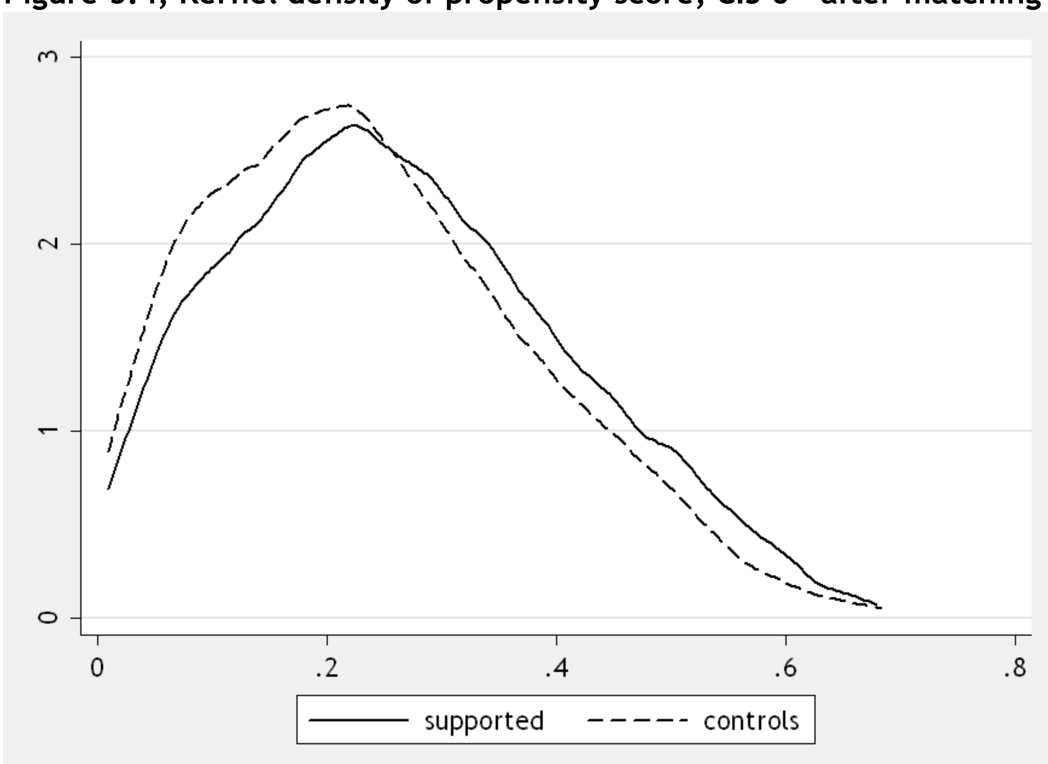


Figure 5.4, Kernel density of propensity score, CIS 6 – after matching



5.9. Appendix – Literature Findings Breakdown

authors / study	**Blanes & Busom (2004)**	**Clausen (2007)**
data set	Spanish manufacturer survey 1990-1996	CIS 3, Norway + R&D survey 1999-2001
procedure	study looks to explain participation	study looks to explain participation
size of ATT		
dep variables	public R&D support (all)	3 different subsidies
industry	carried out by industry	
industry conc.		
mkt share		
size	employment (+ / ***)	sizebands (generally + / varying *)
region		
age	log(age) (varying / not *)	Age-bands (varying / hardly *)
group		dummy (varying / hardly *)
past innovation		patent (always + / mostly **)
export		dummy (always + / always **)
capital intensity		
financial position	cash flow @ t-1 (varying sign / varying *)	
foreign ownership	dummy (domestic) (+ / not always *)	dummy (mostly - / partly **)
growth		firm growth rate (always - / never *)
other	human capital (% graduates) (+ / mostly *)	diversification dummy (always - / hardly *)

authors / study	**Almus & Czarnitzki (2003)**	**Aerts & Czarnitzki (2004)**	**Czarnitzki & Hussinger (2004)**
data set	MIP 95,97,99 manufacturers	CIS 3 (98-00) for flanders (begium) + annual account & patent data	pooled cross section MIP 92-2000
procedure	NN with replacement	NN with replacement	NN with replacement
treatment effect	R&D intensity	R&D spending/intensity; patent/employee	R&D intensity, effect of induced R&D on patent/employee
size of ATT	0.0394	2.47%; 0.036	4.08%
dep variables	public R&D support	public R&D funding	(federal) R&D support
industry	dummies (varying *)	dummies (not jointly *)	dummies (jointly ***)
industry conc.	Sellers concentration (- / *)		Herfindahl @ t-1 (- / not *)
mkt share	mkt share (- / not *)		
size	ln(employment)& square (+ / *),(- / not *)	ln(employment) (+ / ***)	ln(employment) (+ / ***)
region			east dummy (+ / ***)
age	1/age (+ / not *)		lng(age) (+ / ***)
group		dummy (+ / not *)	dummy (+ / not *)
past innovation	R&D department (+ / *)	past patents / employ (+ / ***)	past patents/employ @ t-1 (+ / ***)
export	export/sales (+ / not *)	export/sales (+ / ***)	export/sales (+ / *)
capital intensity	fixed assets/employ	fixed assets/employ (- / not *)	
financial position	limited liability dummy (+ / not *)	cash flow/employ & debt/total assets (+ / not *),(- /not *)	limited liability dummy (+ / not *)
foreign ownership	dummy (- / *)	dummy (- / ***)	
growth			
other	import/sales (+ / not *)		time dummies, import@ t-1 (jointly ***), (+ / not*)

authors / study	**Duguet (2004)**	**Heijs & Herrera (2004)**	**Kaiser (2004)**
data set	French R&D survey 1985-1997	Business Strategy Survey Spanish Manufacturers 1998-2000	2001, Danish survey data
procedure	Kernel Matching	NN with replacement	NN, Kernel and Stratification
treatment effect	R&D/sales	R&D intensity	R&D intensity
size of ATT	between -11% & +4.1%	0.016	-0.92%
dep variables	R&D subsidies	public R&D support (all)	public R&D support
industry	dummies		dummies
industry conc.			type of competitors faced
mkt share			
size	log(sales) (+)	log (employment) (+ / ***)	log(employ); log(emp)^2 (+ / **) , (- / **)
region		peripheral vs central (not *)	
age		Age (+ / not*)	
group			
past innovation	past R&D/sales (+)	formalized R&D & coop (+ / ***)	patent holder& innovator
export		export/sales (+ / ***)	exports (+ / not *)
capital intensity	debt/sales +	capital shares	
financial position			
foreign ownership		% share (- / ***)	
growth		mkt / firm growth	
other	past support (+)	mkt characteristics finance problems # of goods produced (-/not*)	skill structure

authors / study	**Loof & Heshmati (2004)**	**Aerts & Schmidt (2006)**	**Gonzalez & Pazo (2008)**
data set	CIS 3 Sweden 1998-2000	flemish / german CIS3 & 4 + patent data	Spanish manufacturing firms 1990-1999 (panel) survey on firm strategies
procedure	NN with replacement and Kernel (Two NN)	NN with replacement	regression after matching
treatment effect	R&D/employee	R&D spending and R&D intensity	R&D spending
size of ATT	~0.7% (3.9 instead of 3.2)	4.67% & 5.33%	increases by about 8%
dep variables	public R&D subsidies	public R&D support (all) dummy	public R&D subsidies
industry		dummies (jointly ***, ***)	dummies
industry conc.			
mkt share			dummy mkt power@ t-1 (+)
size	employ, employ ^2 (- / ***), (+ / ***)	log(emp) (+ / ***) , (+ / *)	employment@ t-1 (+)
region		east dummy	2 region dummies
age			age (+)
group	dummy (- / ***)	dummy (+ / not *), (+ / not *)	
past innovation	continuous R&D (+ / *)	past patents / employ (+ / ***) , (+ / ***)	
export	dummy (- / not *)	export/sales (- / not *) , (+ / ***)	export dummy @ t-1 (+)
capital intensity	capital/employee (- / not *)		
financial position	equity/employee debt/employee (+ / not *) , (+ / not *)		
foreign ownership	dummy (- / not *)	dummy (- / **) , (- / not *)	dummy for foreign capital (+)
growth			capital growth (+)
other	finance & skill constraint, demand pull R&D (+ / ***),(- /not *),(- /not *)		tech sophistication, abnormal subsidy (+) , (-)

authors / study	**Hussinger (2008)**	**Herrera and Nieto (2008)**
data set	MIP 92-00, manufacturers	Spanish manufacturers 1998-2000 survey on business strategies (SEPI)
procedure		NN without replacement across various regions
treatment effect	R&D intensity	R&D intensity
size of ATT	uses different methods, most get: 0.02	around 2 %
dep variables	public R&D support	public R&D subsidies
industry		medium and low tech dummies (- / partly *); (mostly - / partly *)
industry conc.		
mkt share	mkt share (+ / not *)	
size	log(employment) (+ / **)	
region	east dummy (+ / **)	
age	log(age) (+ / not *)	age (mostly - / not*)
group		
past innovation	patent stock, own R&D department (+ / ***),(+ / ***)	plan & managed R&D ; patents @ t- 1 (+ / always***) ; (alternating / mostly not*)
export	export/sales (+ / **)	dummy (+ / mostly not *)
capital intensity	capital company	difficulty in financing innovation (alternating / not *)
financial position	limited liability dummy (+ / **)	
foreign ownership	dummy (- / ***)	foreign capital % (mostly - / mostly not*)
growth		expanding mkt dummy (+ / partly *)
other	credit rating (+ / hardly *)	government capital % and client (+/ mostly not *); (varying / mostly not *) exports technology; imports technology (mostly + / mostly *) ; (varying / not *)

6. Conclusion

6.1. Introduction

This thesis started out highlighting the perceived poor performance of the UK (as well as Europe) in terms of its R&D spending relative to GDP, a commonly used indicator to measure a countries innovative performance. After noting the latter's importance in driving countries economic growth and competitiveness the introduction chapter described the diversified contributions that have been made to the innovation literature. From this it became clear that innovation is too complex a process to be captured by a single indicator and as a result diversified approaches for its measurement have been developed including the Community Innovation Survey. In this thesis the CIS4, CIS 5 and CIS 6 were used to shed light on the intricacies of innovation as it takes place in the UK. The second chapter explained the significance and limitations of the CIS. The chapter included a detailed description of the CIS content as well as basic statistical summaries of the information that is collected within it, specifically highlighting differences across the survey rounds design affecting their comparability. The next three chapters contained applications of the CIS data which have not yet been undertaken for the UK using the CIS 4, 5 and 6. These included identifying modes of innovation using a hierarchical approach to factor analysis, modelling the determinants of innovation based on the CDM methodology and lastly an assessment of the effectiveness of public support towards innovation using propensity score matching.

The following section details the contributions of this thesis. Firstly this lies in investigating the comparability of the surveys and secondly their empirical applications in chapters 3, 4 and 5. This is followed by section three which summarises the results of the four main chapters. The policy recommendations that can be drawn as a result of these conclusions are detailed in the section thereafter. This is followed by a cautionary note about the limitations of the analysis. The subsequent section points out potential areas of future research with the final section concluding.

6.2. Contribution

This thesis adds the literature on the one hand by establishing to what extent the CIS 4, CIS 5 and CIS 6 are comparable to one another. To this end a description of the differences in the designs of the survey rounds had been undertaken and their impact was investigated in light of the means of the data contained in them. No previous study has provided a comparison of the survey rounds and noted the changes in their design which specifically may impact on the measurement errors that arise. This needs to be taken into account when looking at results obtained from different survey rounds as well as limiting the extent to which explanatory variables can be used for future panel data analysis or when data is pooled. Furthermore three applications of the datasets were undertaken which allowed to see how the differences across the survey rounds' design considerably constrained such work. The choice of these applications represents a major contribution to the literature in that while similar works exist making use of the non-UK CIS, only for the first of these, on modes of innovation, two papers exist that are based on the UK CIS 4 (Lambert and Frenz; 2008, 2010). Albeit the methodology followed in this thesis for identification of the modes is quite distinct from these papers in that it follows a hierarchical procedure for the factor analysis in the spirit of Srholec and Verspagen's (2008) cross country comparison of modes of innovation based on the CIS 3 (not including UK data). The advantage of their approach is that it does not rely on arbitrary selection of variables from the CIS to include and further allows to investigate the so called "lower order" factors derived from the individual question sets and see if they correspond to conceptualizations of the theoretical innovation literature. Furthermore rather than applying orthogonal rotational techniques oblique rotations were used that are in line with the belief that innovation strategies are complementary. For the other two applications no work exists to the author's knowledge that has made use of any of the last three UK CIS survey rounds. While a study by Griffith et al. (2006) exists using the CDM methodology with data from the CIS 3 this was based on a sample of 1,904 UK firms excluding firms from the service sector and those that had less than 20 employees. The research here instead relying on later CIS rounds is based on a population including most of the service sector industries and firms with less than 20 employees (but more than 8), as a result the sample size for the analysis was considerably larger with 13,836 and 11,438 observations for the CIS 4 and CIS 5 respectively. The third application identifies which firms are more likely to be in receipt of public support for innovation. This allowed checking whether firms specifically in need and thus supposed to be targeted by the support for innovation are actually reached by it. No similar analysis exists for the UK. This chapter furthermore provides an assessment of the overall effectiveness of the UK's financial support towards innovation. While past studies estimating the potential effect of introducing an R&D tax credit exist there are no studies for the UK that examine the effectiveness of financial public policy support once the R&D tax credit has actually been put into place. An investigation that as a result of this information being available for the CIS 4 and CIS 6 could be carried out in this thesis. The analysis also allowed to check for the stimulating effect of public support on innovative performance besides just R&D spending intensity, exclusively used in most previous studies. As a robustness check a regression after matching was carried out, also an approach not followed by previous literature but which recently has become best practice. Thus overall through examining the strategies and determinants of innovation and the policy that promotes innovation this thesis makes and important contribution in characterising the recent innovation landscape at the firm level specifically within the UK.

This thesis also adds to the innovation literature by examining the importance of absorptive capacity for innovation in the UK. This capability epitomizes the significance of intangible capabilities for knowledge production and thus innovation. Instead of relying on information about past innovative activities such as the existence of R&D labs and former R&D spending and thus succumbing to a long standing bias towards R&D activities in the literature which is more prevalent in the manufacturing, an alternative measure of absorptive capacity has been generated here. It relies on the firm's self-reported assessment of sources of information used for their innovative activities. This sort of measure is believed to more directly capture the dimensions of absorptive capacity which are related to the "identification, assimilation and exploitation of knowledge". While previous studies exist making use of such a proxy for innovation (Arbussa and Coenders, 2007; Harris and Li, 2009, 2011; Schmidt, 2010) it has not been applied in the context of the CDM framework or in explaining the likehood of the receipt of public support. Similarly a latent variable for appropriability conditions was derived using factor analysis not previously found in the literature and thus allowed to check for decreasing returns to both appropriability and absorptive capacity in explaining R&D propensity and spending in the CDM model.

6.3. Summary and results

Let's turn to the summary of this thesis and its findings. The data chapter shortly described measurement of innovation using R&D and patent data and their respective limitations. It then explained how part of these were overcome through the Community Innovation Survey. It has detailed past criticisms of the literature directed at the CIS, these include the lack of information on the organisational aspects of innovation including human resource management, specifically because they are recognized to have important bearing on the firm's absorptive capacity (Jansen et al. 2005; Bloch, 2007; Schmidt, 2010). The chapter has also highlighted issues that influence the comparability of the survey rounds, namely in its design and wording of questions. The sample as to whom the question about barriers of innovation is directed varies in each survey round, however these changes can actually be used to investigate whether innovators or non-innovators are affected and in which ways since there exists hardly any research on this topic. Some of the question sets have now (mainly starting with the CIS 6) been limited to only the firms considered innovation active including the one about sources of information judged important for innovation by the respondents. This means identification of an absorptive capacity measure for all firms is no longer possible when they all must possess this ability to one or another degree even if they are not innovation active during the survey period since this ability is intrinsic to human and thus the management's cognition. Likewise the question about appropriation methods deemed important has been replaced by one about patents, design registrations, trademarks and copyright applied for. While this sort of information provides alternative measures of innovative outputs it means the appropriability conditions specific to a firm's distinct market can no longer be characterised. The lack of information about appropriation methods as well as information sources shown to be important for innovation has meant that the analysis based on the CDM framework could only be carried out for the CIS 4 and the CIS 5. The analysis was devised to see the contribution of these two firm properties at a time when the CIS 6 had not been conducted yet or its design made available. Furthermore since the information about the receipt of public support was only available for the CIS 4 and the CIS 6 the investigation of what determines the likehood of receipt as well as the impact this has on innovative performance could only be carried out for these two datasets. Similarly the analysis of the modes of innovation was restricted to firms deemed innovation active according to the CIS 6 as large parts of the question sets were only directed at these firms. These differences across the surveys besides the aforementioned issues of differing measurement errors thus limit the extent of the information that can be used for cross survey comparisons or panel data analysis. The confusion about the meaning of "innovative activities" and similar terms as well as the definition of innovation itself which vary among the surveys is a major issue that has been identified. The observed differences across the data means for the various surveys particularly for the continuous information such as innovative activity spending clearly suggests that measurement errors have changed across the surveys very likely in parts as a result of the changes in the surveys' design. But they will also be in part due to poor efforts and ignorance on part of the respondents. This finding suggests that the survey rounds are unfit for panel data analysis as the resulting changes in measurement errors means they will not simply difference out. A conclusion that is further aggravated by the overlap of the survey rounds by one year which may lead to double counting. Of course with respect to comparability the two aims of the survey are expected to be at a tension with one another. That is on the one hand to be comparable across time, countries and regions and on the other hand to reflect and expand our understanding of innovation.

While the survey is based on the Oslo manual which stresses the systemic nature of innovation it could as previous research suggested be more adept at accounting for the systemic nature of innovation and the role of public support. This could be achieved by including information on linkages among institutions involved in forming an innovation and at which stage of the innovation process this involvement takes place. Besides more details as to the types of government support received by firms including estimates of their financial size would be useful for future research. As it stands in the CIS, a survey which should help assessing the effectiveness of policy, the already scant information about the role of public support for innovation has been further decreased. Though the CIS 6 unlike its predecessor again included a section about the receipt of public support, it solicits no information about whether firms have also received support in the form of R&D tax credits as found in the CIS 4 or which broad types of programmes they participated in as found in the CIS 3. The former omission is thought to potentially explain the decrease in the proportion of firms in the CIS 6 reporting to have received support for innovation. The questions relating to the support for innovation have again been removed completely in the CIS 7 (BIS, 2012).

Nonetheless the applications of the UK CIS have provided researchers with a rich set of insights into the innovation process and likewise this thesis is believed to have contributed to these. The first empirical chapter has been able to identify two major modes of innovation as captured by the survey. A 'traditional' or 'linear' strategy aimed at introducing product and process innovations, relying on innovative activities such as R&D and also making use of sources of information, more strongly from market sources then from science sources. Secondly a 'dynamic' or 'systemic' strategy also involving innovative activities such as R&D but more strongly making use of knowledge sources from science as well as relying on cooperation. The interpretation of this "blue skies strategy" as it is not directly linked to achieving technological outputs is that it generates knowledge that helps to keep abreast of market developments and to be ready to spot opportunities as posited to be central to a firm strategy by the literature on dynamic capabilities. Compared to the results by Lambert and Frenz (2008, 2010) and Srholec and Verspagen (2008) the identified factors herein allow for a more plausible theoretical interpretation and are appealing due to their simplicity. The lower order factor analysis often cannot confirm theoretical dichotomies such as formal and informal protection methods, i.e. these concepts are rather of complementary nature. In this chapter likewise using the technique of factor analysis a measure of absorptive capacity based on sources of knowledge deemed as important by firms for their innovative activities was created. Similarly a measure of appropriation based on firm's assessment of the importance of appropriation methods to protect their innovations has been generated.

These measures were then shown to play a significant role in explaining innovative activities in the subsequent empirical chapter, both exhibiting decreasing returns to scale. This chapter following the CDM methodology has confirmed that knowledge capital as proxied by predicted R&D spending intensity is as important in generating service innovations as it is in causing goods innovations. The results also show that absorptive capacity not only indirectly impacts the likehood of introducing service innovations through its effect on knowledge capital as for goods innovations but also directly. This suggests that services once conceived further have to be tailored to individual customer's needs. This finding highlights that absorptive capacity is specifically important in a developed economy dominated by the service sector. At the same time the fit of the models confirmed that the CIS could do better at explaining service and process innovations by soliciting more information that are likely to cause these types of innovation. Finally the chapter provided further support for the innovation productivity nexus.

The last empirical chapter then confirmed that absorptive capacity is also an important factor explaining the likehood of firms to be in receipt of financial public support towards innovation. This chapter also concluded that the financial public support towards innovation in the UK has in the recent past been effective at stimulating innovative performance besides just R&D spending. The government's objective of supporting start-ups, that potentially face difficulties in financing their innovative activities, as well as supporting cooperation, vital for the dissemination of knowledge in the economy, is met according to the results. However SMEs could not be shown to be statistically more likely to be in receipt of public support despite facing the same problems as start-ups, though at least they are not less likely to be in receipt of public support then large firms. This finding stipulates that policy objectives are not achieved with regard to specifically targeting SMES.

6.4. Limitations

There are some limitations to this study. The chapter on modes of innovation affirms that factor analysis is complicated by the choices the researcher needs to make regarding its implementation which may influence the number and types of factors retained and thus their subsequent interpretation. But also that for this very reason the use of several survey rounds allows obtaining more robust results. For the third chapter as well as the fourth one since all of the analysis is based on cross sectional data no direct causality of the identified correlations can be claimed, though this argument is weakened by the evidence about the persistence of innovative activities[266]. Particularly because this is a shortcoming so common to studies in this field it is paramount to ensure the comparability of the data across the survey rounds in the future so that this criticism can be overcome by use of time series analysis. Most importantly because innovation is a dynamic process that takes place with varying lags and feedbacks, features that can due to the cross sectional nature of the data not be adequately accounted for in this study. A limitation of the last empirical application is that the conditional independence assumption cannot be tested.

6.5. Policy implications

The policy implications of this thesis based on the results of the empirical applications are not only because of the aforementioned limitations to this work to be considered with caution. This is because the development of the CIS dataset on which they are drawn is hopefully still at an early stage and likewise is the literature about innovation which it is based upon. Specifically the recently emergent systemic literature has highlighted the potentially too narrow conceptualization of the innovation process and thus understanding of the factors that influence it. Policy makers which have quickly taken a liking to the innovation systems label however need to properly grasp what it entails. Hence the bias

[266] Hall et al. (1986) for R&D and patents, Lach and Schankerman, (1989) for R&D and capital investment, Cefis (2003) for patents, Peters (2009) for degree of internationalisation, availability of finance and technological capabilities. This is in line with observations on the persistence of productivity of firms (Bartelsman and Doms, 2000); Griffiths (2010) also shows that firm internal characteristic are time-invariant factors (ie our data from the CIS) explaining most of firms R&D activity.

towards R&D spending figures as for instance seen in the Lisbon Strategy needs to be overcome and replaced by an appreciation of the more diversified information indicators as available in the European Innovation Scoreboard and the Community Innovation Survey[267]. At the same time as Freeman and Soete (2009) point out one needs to devise measurement methods for areas of innovation that are presently difficult to capture, comparing the situation with the person at night looking for his lost keys only where the streetlamp sheds its light. Furthermore as they note a focus on one or few measures of innovation is likely as Goodhart's law (1975) states to lead eventually to a weakening of their correlation with actual innovative performance. However such relations can only be established if the information about types of policy support received by firms gets extended again to at least the level present in the CIS 3 rather than being completely dropped as is the case for the CIS 7. Finally it is paramount to ensure that survey information is comparable and reliable by sticking to at least a consistent survey core design as well as providing an explicit definition of what the term "innovative activities" or its derivatives stand for. Otherwise it is not clear to what extent the fluctuations identified are a result of actual changes of the behaviour of firms or influenced by changes in the survey design and resulting measurement errors.

Let's turn to the more direct policy implications of this work for the UK, which in light of the above argument are kept broad in nature. It has been confirmed that an important part of a firm's innovation strategy is to generate knowledge to be able to keep abreast of market developments. At the same time knowledge capital has been shown to be significant in contributing to innovative outputs while absorptive capacity has been confirmed to be an important contributor to both of these. The government hence needs to further knowledge dispersion by maintaining its financing of public and private research particularly because the latter of the two has been shown to be effective. Since absorptive capacity plays and important role at the economy wide level its attempts to support networks that connect actors in the innovation landscape need to be maintained. Based on the results of the model explaining the likehood of receiving support for innovation policy needs to reach

[267] Also see the work of Arundel and Hollanders (2005) who similar to the approach taken in chapter 4 using factor analysis of the CIS 3 and linked statistics create an Exploratory Innovation Scoreboard (EXIS) to complement the EIS.

more SMEs specifically due to the problems they face in financing their innovative activities. These areas require sustained investment despite the present austerity regime as they are contributors to the long run growth and competitiveness of the UK.

6.5. Suggestions for Future Research

This research has confirmed the important role of absorptive capacity for innovation. Absorptive capacity is related to the organisation of human capital in which knowledge is embedded which in turn is related to the employees own absorptive capacity. It is however not clear how an individual's absorptive capacity translates to a firm's absorptive capacity. In other words little empirical evidence exists on how exactly work organisation influences absorptive capacity (examples are Jansen et al., 2005 and Schmidt, 2010). It seems important to collect further evidence in this respect to be able to more accurately conceptualize absorptive capacity. The argument by Arbussa and Coenders (2007) that the information on barriers to innovation reflects realized absorptive capacity needs to be investigated by seeing how far it is actually related to the "transformation and exploitation of knowledge". If the CIS sees no changes that would be able to capture the organisational dimensions of absorptive capacity the two aforementioned avenues require researchers to collect their own data ideally linked to observations contained in the CIS. This could also allow to see to what degree alternative measure of absorptive capacity including past R&D spending available from CIS panel data are correlated and which ones more significantly contribute to innovative performance and are thus able to capture the notion of absorptive capacity. Another interesting possibility for future research from a systemic viewpoint is to see how the firm's absorptive capacity translates to the country's absorptive capacity identifying the institutional aspects important to the matter. Future research should also be able to look more specifically at the impact of the ever changing individual support programs and firms linkages with public institutions (Bloch, 2007) to be able to gauge their impact on the innovation process, if necessary again by collecting this information separately. It could also investigate issues pertaining to the relationship between effectiveness of policy and the location of firms being in the core or the periphery as previously identified for Spain by the work of Herrera and Nieto (2008). Similarly Harris, Li and Trainor (2009) suggest that research could look at whether public support has different effectiveness for different regions.

6.6. Conclusion

This chapter concludes the thesis. It started off by outlining the contributions of this thesis. These include the use of newly available data from the three recent CIS rounds and investigate the comparability of these. They also lie in generating an alternative measure of absorptive capacity that is not biased towards R&D and that could be used in analysing its impact on innovative activities and outputs as well as the likehood of receipt of financial support towards innovation. Next the contents and findings of the main chapters were summarised. This included areas across the three survey rounds that have changed significantly and thus limited the samples and question sets that could be used for the applications carried out in this study as well as leading to differing measurement errors impeding its use for panel data and trend analysis. The thesis has confirmed the role of absorptive capacity in explaining firm's innovative activities but also in explaining the likehood of receipt of public support. However the support is not effective at specifically reaching SMEs. The thesis has found evidence that shows the effectiveness of financial support towards innovation. Nevertheless in light of limitations to the study the results have to be treated with some caution. These include the cross sectional nature of the data and related to that a lack of consensus on the exact theoretical underpinnings of the innovation process. The policy recommendations noted in this chapter are in part linked to these limitations which imply the need to finance future research but also ensuring comparability of the CIS as well making adjustments to it to reflect and to expand scholarly thinking. The findings have highlighted the importance of knowledge for innovation and how its generation as well its dissemination through furthering absorptive capacity are important policy objectives to be maintained. Lastly understanding of the dynamic nature of innovation as well as absorptive capacity and barriers that firms face when innovating are areas of research that require future attention.

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