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A Microeconomic Study of Exporting and Innovation Activities and Their Impact on Firms: A Resource-Based Perspective

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Abstract

Various models explaining micro knowledge-generating behaviour (in particular exporting and innovating) in the economics literature are underpinned by the overlapping assumption that these activities are largely determined by the resources/capabilities possessed by firms. Despite their perceived importance, there is a dearth of evidence on how these heterogeneous resources and firm-specific capabilities can be incorporated into economics models to quantify their roles in determining microeconomic behaviour. Therefore this thesis attempts to bridge this gap in the literature by integrating the resource-based view (RBV) as a new IO theory into the microeconomics literature and empirically utilising micro level data to investigate the significance of such resources/capacities in determining exporting and innovation activities, moderating their inter-relationships as well as conditioning their impacts on the firm's performance.

These heterogeneous resources have been proxied using firm size, productivity, capital intensity, intangible assets, various dimensions to absorptive capacity, the deployment of R&D sourcing strategies and so on. Using establishment-level data covering all UK market-based sectors in 2000, the findings show that all these factors have a large impact upon the propensity and/or intensity of establishments' exporting and/or R&D activities, with an especially noticeable role in breaking down entry barriers to undertaking such activities. Given the significant impact of exports on knowledge-creating R&D activity, the thesis subsequently investigates and confirms additional learning effect of exporting as embodied in the firm-level exports-productivity relationship using a nationally representative panel dataset covering both manufacturing and services sectors in the UK, for the 1996-2004 period. Lastly, this thesis also attempts to provide an initial inspection of the contribution of innovation (proxied by R&D stock) to productivity using plant-level panel data for Northern Ireland. Based on the estimation of a 'knowledge production function' separately for various manufacturing industries, the overall long-run results show that R&D stock does have a positive impact upon productivity.

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Exporting, R&D and Absorptive Capacity in UK Establishments (with R. Harris), *Oxford Economic Papers*, 2009, 61(1), 74-103.

FDI and Labour Demand Adjustment to Factor Prices and Demand Shocks in the UK Manufacturing Industry (with S. Girma) In: Harrison G. Blaine (eds) *Foreign Direct Investment*. 2008 4th Quarter. New York: Nova Science Publishers.

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Author's Declaration

List of Abbreviations

ARD	**Annual Respondents Database**
BERD	**Business Enterprise R&D**
CIS	**Community Innovation Survey**
FAME	**Financial Analysis Made Easy**
FDI	**Foreign Direct Investment**
IV	**Instrumental Variable**
KPF	**Knowledge Production Function**
MNE	**Multinational Enterprise**
n.e.s	**not elsewhere specified**
ONS	**Office for National Statistics**
R&D	**Research and Development**
RBV	**Resource-Based View**
RHS	**Right-Hand-Side**
RTS	**Returns to Scale**
SME	**Small and Medium Enterprise**
TFP	**Total Factor Productivity**

Chapter 1: Exporting, Innovation and Their Productivity Impacts from a Resourced-Based Perspective

1.1 Resource-Based Economy vs. Neoclassical Paradigm

The resource-based theory of the firm was initially put forward by Penrose (1959), and subsequently developed by Wernerfelt (1984), Barney (1991, 2001) and Peteraf (1993). From an economic perspective, the resource-based view (henceforth RBV) holds that a firm can generate higher 'Ricardian' rents[1] from the utilisation of firm-specific assets which cannot be replicated by other firms. Particularly, in addition to the conventional tangible assets which operate through relatively clearly defined markets, there are intangible assets (Griliches, 1981), or firm-specific capabilities (Pavitt, 1984; Teece and Pisano, 1998), which largely determine the dynamic capabilities that define a firm's competitive advantage. The thrust of the argument is based on the established assumption that 'better' firms possess intangible productive assets that they are able to exploit to derive competitive advantages, for instance, specialised know-how about production, superior management and marketing capabilities, export contacts and coordinated, quality-orientated relationships with suppliers and customers (Hymer, 1976).

The RBV essentially seeks to provide an explanation for the sustained differences amongst firms (particularly in terms of performance or profitability as originated in the strategic management literature) by identifying and analysing the heterogeneity in firm resources. In particular, valuable and scarce resources could render the firm a competitive advantage over its rivals, thus leading to better performance; at the same time, the sustainment of such competitive advantage will require the resources to be non-replicable and non-substitutable so as to deter any competition from rival firms. In essence, such a resource-based and organisational capabilities approach to the firm is concerned with how resources, skills and capabilities (be tangible or intangible assets) are generated,

[1] Defined as returns in excess of their opportunity costs, to distinguish them from monopolistic rents when firms restrict output.

accumulated and deployed (Barney, 1991; Kogut and Zander, 1996; Teece *et al.*, 1997). The literature in this area concentrates on the firm defined as bundles of various assets, essentially technology, capital and labour (*c.f.* Penrose, 1959). It follows that the emphasis is on internal characteristics, rather than the external environment (Barney, 1991), and thus what a firm possesses determines what it can accomplish (Rumelt, 1984).

In a modern era, the significance of such a resource-generating process can be better understood by identifying firms' economic motivations for growth and performance from both the demand and supply perspectives. On the one hand, the modern era is shaped by unprecedented level of globalisation, innovation and technology leading to ever changing structures of industrial organisation, increasing competition and costs (e.g. relating to production or transaction), as well as difficulties in recruiting/retaining highly skilled labour to maintain its competitiveness. In this sense, market demand conditions are generally recognised to play a remarkable role in a firm's decision-making process. This demand-side drive implies that the firm has to upgrade its resource base more proactively so as to meet the ever increasing demand and therefore realise additional profits, which can be reflected by the outward shift of the demand schedule (mainly due to innovation and technology). On the supply/cost side, cost minimisation has always been a traditional and primary incentive for the firm to acquire more (especially knowledge-based) resources and achieve higher growth, for instance, the lowering of labour costs through investment in R&D to substitute for labour input. In addition to labour saving devices, some other cost incentives have also been addressed in the literature to explain the firm's resource/capacity-building behaviour, such as saving in time and space as prevalent in recent IT revolution (Crespi *et al.*, 2003). These resources can be generated and/or upgraded both internally through the processes that improve the firm's internal capabilities as well as externally through its acquiring and appropriating knowledge outwith itself.

This resource-based approach to understanding the economy and firms as its main agents is a distinctive departure from conventional *neoclassical economics* as advocated by various schools of thought. Conventionally in the neoclassical paradigm, the representative firm is studied in the context of an economy based on the production and exchange of goods and services, often in a static framework. In stark contrast, the RBV treats resources as fundamental productive entities and the economy as being constructed on these resources – the dynamic and productive assets of firms – which hold the key to firms' distinctiveness; in other words, there is no such a thing as a 'representative firm' in a resource-based economy (vis-à-vis the neoclassical IO synthesis), where each firm is treated in all its heterogeneity, ranging from the firm-specific heterogeneous endowment of assets at start-up, the heterogeneous process of acquiring, utilising, and exchanging endowments through the dynamic development of its resource base and interaction with other firms, to the heterogenous outcome of such development — distinct productivity/performance levels. It is worth noting that the principle distinction of the RBV lies in its focus on the resources (as opposed to goods and services as in the mainstream neoclassical IO synthesis), which are the fundamental productive entities of production and exchange. Unlike goods and services, such resources do not exist outside the firm, but are only contained within the firm; they can be developed by firms internally as well as traded/acquired from outside.

Nevertheless, the RBV and the neoclassical framework for understanding firms and the economy may only be depicting two sides of the same coin. From firms' perspective, the primary interest lies in the configuration of resources – their distribution in heterogeneous bundles within and between firms. From the economy's viewpoint, what is of paramount importance is the dynamic capacity of the economy – its capability of creating new resource configurations and the evolutionary pathways along which such processes of resource configurations develop. These resources, in their totality, account for the production of the goods and services described in conventional neoclassical economics. Therefore, it is the same economy we have been used to dealing with; however, with the RBV, it is the unobservable in the production black box that is being accounted for, which has been long neglected before, using the heterogeneity in resources to provide a different perspective to explain some observed distinctions in production outcome (Mathews, 2002).

Last but not the least, in this resource-based framework, many firm-specific factors are argued to impact upon the development of a firm's resource base, with one of the most influential factors being organisational size. Academic interest on the relationship between firm size and performance probably dates back to Schumpeter (Schumpeter, 1947). The positive impact of organisational size on productivity is traditionally explained by economies of scale and scope, which may enable firms to access financial capital with more ease in an imperfect capital market, spread risks and/or fixed costs over a portfolio of projects, take better advantage of external resources and diversify own products easily so as to have greater opportunities to reap scale and scope economies. In the context of the firm's evolutionary growth in a resource-based economy, it calls for the possession of substantial managerial and organisational resources and capabilities in order to acquire, absorb and utilise knowledge to develop competences. It follows that organisational size facilitates the mechanism of learning; in other words, firm size increases the likelihood of learning via both internal and external sources. As argued by Almeida *et al.* (2003), startup size enhances the opportunities to access external knowledge (due to the increased number of interfaces to the outside world) as well as assimilates and applies this knowledge internally (thanks to the resource-generating activities taking place within the firm). Nevertheless, on the other side, there may also be diseconomies associated with size, which are well documented in both theoretical and empirical literature. For example, Levinthal and March (1993) argue that larger firms tend to concentrate on knowledge merely related to their own experience due to inertia, complacency, or resistance to change, and therefore become more inward-looking and short-sighted of more distant knowledge, which is termed the 'myopia of learning' by the authors.

1.2 Innovative Activity from an RBV Perspective

1.2.1 Knowledge, Innovation and the RBV

The RBV maintains that a firm's dynamic capabilities are a sub-set of its competences and capabilities that allow the firm to create new products and processes, and to respond to changing market conditions; they are the core of its competitiveness. According to Teece and Pisano (1998), these dynamic capabilities shape (and are shaped by) 1) the firm's managerial and organisational processes (e.g. its 'routines' or current practices and learning[2]);

[2] Nelson and Winter (1982) refer to this as the collectivity of routines.

2) its position (e.g. current endowment of technology and intellectual property); and 3) its paths (e.g. alternatives available which will lock it into a trajectory, i.e. the notion of path dependency; *c.f.* David, 1985; Arthur, 1989).

To illustrate these points further, firstly, 'processes' are essentially concerned with how a firm learns to behave such that its routines and practices epitomise the 'culture' of the business – the idiosyncratic way the firm operates, covering how it searches for opportunities, how it learns and processes threats and opportunities, how it mobilises creativity and innovation and how it manages learning and knowledge accumulation activities (Bessant *et al.*, 2001). In all, such processes define the firm's problem-solving capability; they evolve over time and cannot be copied in any simple fashion.

Secondly, as stated above, the firm's 'position' not only reflects its current endowment of technology and intellectual property, but also other assets such as relationships with key suppliers and customers – thus such competence is firm specific and mostly describes the static environment in which the firm currently operates. Lastly, in contrast, the 'path' of the firm refers to the strategic direction it takes, and as such is both firm specific and shaped by its past experience and activities. Such a technological trajectory is thus path-dependent.

For instance, with an emphasis on dynamic capabilities, Teece (1996) sets out what he considers the fundamental characteristics of technological development: its uncertainty, path dependency, cumulative nature, irreversibility, technological interrelatedness (with the complementary assets), tacitness of knowledge (organisational routines) and inappropriability. All of this points to the outcome that technological 'know-how' is 'locked-in' to the firm and future alternatives are path dependent. Fundamentally, Teece and other proponents of the RBV argue that such competencies and capabilities by their very nature cannot be bought but only built by the firm. That is, the factors that determine this rate and direction cannot easily be acquired, replicated, diffused, or copied – the capacities therefore cannot easily be transferred or built up outside the firm. This, in part, comes from the key role that learning plays both in enabling the firm to align its resources, competencies and capabilities, and in allowing the firm to internalise information outwith the business into knowledge; and the way the firm learns is not acquired but determined by its unique ‘routines’, culture and its current position (stock of knowledge).

Thus, processes of knowledge generation and acquisition within the firm are essentially organisational learning processes (Reuber and Fisher, 1997; Autio *et al.*, 2000). The processes of incremental learning are important sources of both codified and tacit knowledge which may have great impact on competitiveness. Although firms could develop and acquire much of the knowledge internally (through their own resources and routines), few virtually possess all the inputs required for successful and sustainable (technological) development. Therefore, the fulfilment of firms’ knowledge requirements necessitates the use of external sources to acquire and internalise knowledge (Rosenkopf and Nerkar 2001; Almeida *et al.*, 2003 set out the main external sources of knowledge available to firms).

This relationship between internal and external knowledge sourcing is complex in nature. Much of the theoretical literature concerned with transaction-cost economics and property rights considers the choice between internal development and external sourcing (i.e. the ‘make’ or ‘buy’ choice — see p.14 for a more detailed discussion on this); and the conditions that may favour one route over the other, or not to proceed with a particular development at all (Coase, 1937; Williamson, 1990). As discussed above, the RBV of the firm stresses competences and internal capabilities as key elements in determining firm performance and it is appropriate to consider these factors in relation to the processes of knowledge acquisition, transfer and conversion. In a modern era characterised by rapid technological change and increasing competition, the firm’s in-house capacities and resources become hardly sufficient for solving complex problems and thus need to be complemented with the knowledge and resources of other firms. Consequently an increasing number of firms establish co-operative links with others to facilitate their access to external knowledge.

1.2.2 Innovation and R&D

> As soon as quality competition and sales effort are admitted into the sacred precincts of theory, the price variable is ousted from its

> dominant position… But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organisation (the largest-scale unit of control for instance) − competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives. This kind of competition is as much more effective than the other as a bombardment is in comparison with forcing a door.
>
> Schumpeter (1947), pp.84-85

The notion of (technological) innovation encompasses the development of new or improved products and processes, change in value activities like administration and service provision, or more generally the initiation and management of commercially significant change. In providing an explanation of the incredible growth of the free-market economies in modern era, Baumol (2002) recognises technological innovation as the fundamental driving force behind the growth of capitalism, arguing that "*under capitalism, innovative activity-which in other types of fortuitous and optional-becomes mandatory, a life-and-death matter for the firm*". As a matter of fact, the linkage between innovation and economic growth is not linear, but with a multiplier effect.

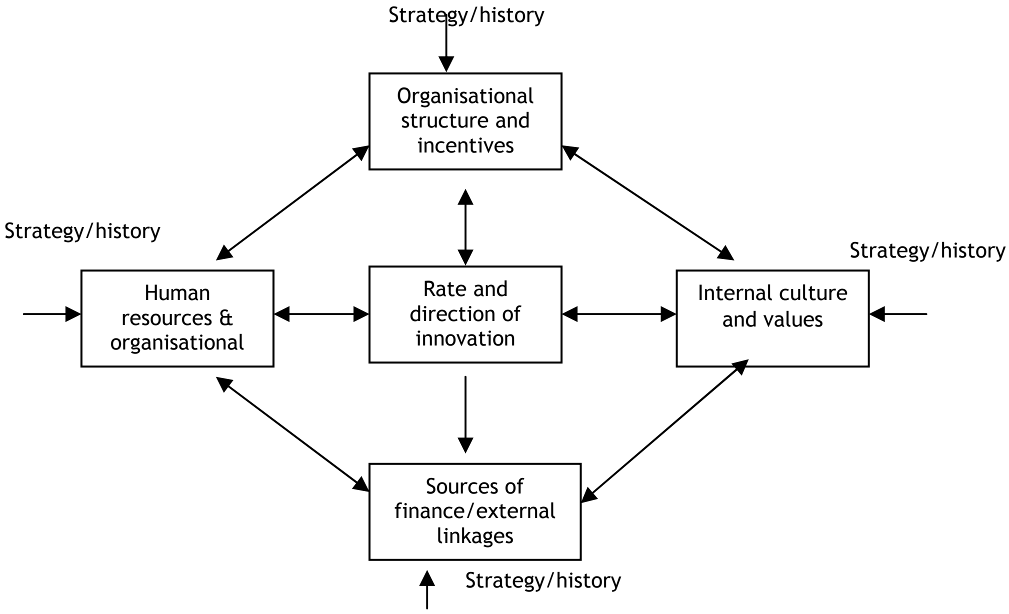
Evolutionary theory predicts that the interaction with innovative/technological factors renders firms an important impetus to survive and develop through enhancing their resource base and learning capacities in a dynamics environment (*c.f.* Nelson and Winter, 1982). It follows that innovation holds the key to firms' acquisition and sustainment of competitive advantage and thus performance improvement. There exist various dimensions to technological innovation, with the principle one being its nature as a public good frequently embodied in the form of information (Arrow, 1962). Consequently the benefits of innovation normally cannot be fully exploited by the investing firm, and therefore such innovative outcomes often spillover to other firms and ultimately enhance the knowledge stock of the economy by disseminating such specialised and technologically-advanced knowledge in the wider economy. Another characteristic of innovation that facilitates the expansion of the resource/knowledge base of the firm/economy lies in its cumulative nature. In particular, when new innovative products/ideas are introduced, they do not simply become substitutes of previously developed products/ideas, but rather, they add to the existing knowledge stock and push the technological frontier further outwards for the firm and the economy.

From an RBV perspective, a firm's capacity for innovative activities, amongst other resources, plays a crucial role in its dynamic development and strategic competitiveness. According to Barney (1991) and other advocates of the RBV, innovation confers the competitive advantage on the firm to generate unique, inimitable, valuable and diversified products and hence enhances its survival prospects and performance. Nevertheless, on the other side, as Baumol (2002) puts it, firms do not wish to risk too much innovation, since undertaking novel innovation necessitates substantial investment of resources and could be easily made obsolete by rival competition. As a result of such costly nature of innovation, firms have split the difference through selling technological licenses and participating in technology-sharing compacts which pay considerable dividends to the economy as a whole, and therefore turned innovation into a routine feature of economic life. It follows that firms constantly need to strengthen their innovative capacity through investment in internal development alongside appropriation of external factors.

Indeed, since a firm must consider its rivals' reactions to R&D, it must consider the extent to which inventive activities can be appropriated until the firm has managed to recover its investment. For this reason, *inter alia*, R&D is regarded as an (irreversible) sunk cost and consequently it becomes harder to finance it through external funds. Thus, in his well-cited work, Schumpeter (1947) argues that a necessary reward to make inventive activities worthwhile is the mere expectation of a monopoly position conferring market power (i.e. raising price above average costs). Geroski (1990) subsequently considers actual monopoly power in terms of its direct and indirect effects, with the former including the ability of monopolists to use high current monopoly profits to provide more (and/or cheaper) internal finance and resources for R&D, while the latter indirect effects acting through current market power increasing the expected post-innovation price-cost margin which, in turn, has a positive effect on current R&D spending. Thus Geroski suggests a significant positive impact of market power upon the extent of innovation activity, having controlled for inter-industry differences in technological opportunity.

Another important aspect of innovation is to do with the relationship between such innovative assets and other resources that a firm possesses and that define the firm. In the context of heterogeneous resources available to firms, the RBV approach to understanding innovation activity (be it incremental or radical) also emphasises the relationship between such innovative assets and other complementary assets possessed by the firm (e.g. Teece's approach as discussed below); that is, there is no artificial dichotomy placed on technology being separate from other aspects of what define the firm. Figure 1-1 (a reproduction of Teece's model, 1998) provides a holistic picture of how innovation interacts with and is affected by various other firm-level assets. In particular, this conceptual model highlights the complexities, the path-dependent nature of firm-specific attributes as well as their interaction. The majority of firms recognise that 'best practice' is a coherent system rather than a collection of independent techniques. As Figure 1-1 illustrates, the whole innovation system is centring on the rate and direction of innovation within the firm, which nevertheless is then influenced by organisational structures, human resources, culture, values as well as external finance. This system of innovation is further complicated by the fact that there are multi directions of such impact. Therefore, it is important to consider such complementary assets – which are crucial to the successful development of technology and ultimately, firm performance – within a wider context of organisational assets, human resource assets, cultural and external linkages.

Figure 1-1: Determinants of the rate and direction of firm-level innovation



Source: Teece (1998)

In addition, it is generally held that there is also a strong *regional dimension* to the distribution of firm innovation activity. There is a growing body of literature on regional innovation systems underpinned by the role of knowledge (tacit knowledge in particular) and the notion of the 'learning region' (Cooke and Morgan, 1994; Oughton *et al.*, 2002; Cooke *et al.*, 2003; Howells, 2002; Asheim and Gertler 2005). For instance, Acs *et al.* (2002) present both theoretical and empirical evidence for a positive relationship between a region's current stock of knowledge (as measured by innovation/patent counts) and its private and public R&D expenditure. Regional proximity facilitates the diffusion of tacit knowledge and thus the firm's learning behaviour, which may be reinforced by agglomeration economies in production and pools of skilled human capital. The innovative ability of firms in a region is critically dependent upon the learning ability of a region namely, the ability of regional economies to create, assimilate and transform technological knowledge. Moreover, the regional effect on innovative activity is further substantiated by the significance of regional R&D spillovers. More detailed discussion of the geographical aspect of innovation is provided in Chapter 2 (pp.49-54).

There are usually two sets of measures for firms' innovation activity. Above all, innovation could be proxied using innovative outputs such as number of patents obtained, process or product innovations and so on. Nevertheless, due to the inherent difficulty in compiling such data, measures from the output side are relatively difficult to come by. In contrast, on the input side of innovation, the concept of effort to innovate is usually investigated using both absolute measurements such as investment in R&D activity, number of employees involved in R&D related activity etc., supplemented with relative measurements such as R&D intensity (often defined as the proportion of R&D expenditure over total sales), R&D expenditure per employee etc.

Nieto and Quevedo (2005) have reviewed 15 studies in the literature with respect to firms' innovative effort (Table 1, pp.1144-1145) and concluded that R&D activity is the most widely deployed proxy for a firm's innovation despite its limitations vis-à-vis some output measures of innovation. A major explanation for R&D's popularity as an indicator of innovation lies in the fact that firm-level investment in (in-house) R&D is strongly affected by, *inter alia*, the firm's current level of innovation; that is a causal link exists between innovation and R&D at the micro level in that the firm's decision to increase its present level of R&D spending is conditional on its past success (or experience in general) in generating innovative outputs. Indeed, from an RBV perspective, R&D activity holds the key to determining the firm's technological capacity by systematically broadening its current resource-base and stock of knowledge, efficiently applying such resources/knowledge to commercial ends (by generating innovations), and at the same time, enhancing the arrival rate of innovative outputs (be either process or product innovations). Moreover, R&D is also undertaken on grounds of its positive influence on productivity and performance (see Chapter 6 for an investigation into this R&D-productivity nexus). Therefore, unsurprisingly, it is well-documented in the empirical literature that the firm's R&D expenditure is significantly positively related to its innovations (e.g. Acs and Audretsch, 1988; Feldman, 1994; Kleinknecht, 1996; Freeman and Soete, 1997; Shefer and Frenkel, 2005).

1.2.3 Innovation and Absorptive Capacity

The notion of absorptive capacity is of paramount importance to understanding the implication of RBV for the generation and sustainment of competitive advantage in individual firms. Knowledge and learning can be expected to have a fundamental impact on growth in that firms must apprehend, share and assimilate new knowledge in order to compete and grow in markets in which they have little or no previous experience (Autio *et al.*, 2000). From an RBV perspective, absorptive capacity is often regarded as a strategically valuable capacity due to its firm-specific, path-dependent and evolutionary nature in appropriating external resources/knowledge for the generation of competitive advantage. Basically, absorptive capacity constitutes an analytical link between the firm's in-house resources and the external stock of knowledge in enhancing its resource base and generating competitive advantage. In a seminal paper, Cohen and Levinthal (1990) demonstrate that the ability to exploit external knowledge is a critical component of a firm's capabilities. They argue that

> ...the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge. At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Thus, prior related knowledge confers an ability to recognize the value of new information, assimilate it and apply it to commercial ends. These abilities collectively constitute what we call a firm's 'absorptive capacity'.

Their analysis first considers the absorptive capacity of the individual and its cognitive basis, including the importance of prior related knowledge for learning (i.e. assimilating existing knowledge) and diversity of background. These are important because, even if knowledge is nominally acquired, subsequently it will not be well utilised if the individual does not already possess the appropriate contextual knowledge and prior experience. Problem solving skills represent the capacity to create new knowledge and develop in a similar way to learning capability. Prior knowledge and skills, which permit recognition of associations and linkages that may never have previously been considered, provide a foundation for creativity.

In summary, the ability to assimilate information is a function of the richness of the individual's pre-existing knowledge structure. This implies that learning is cumulative and learning performance is greatest when the object of learning is related to what is already known. As a result, learning is more difficult in novel domains, but even in this case a diverse background will increase the probability that incoming information will relate to something already known.

The authors then examine the absorptive capacity of the organisation, which tends to develop cumulatively as well. While it depends on individual absorptive capacities, it also depends on transfers of knowledge across and within sub units that may be quite removed from the original point of entry. Knowledge transfers across boundaries are primarily determined by the structure of communication between the external environment and the organisation, the structure of communication amongst its sub units, and also by the character and distribution of expertise within it; that is, it depends on the links across a mosaic of individual capabilities. The firm's absorptive capacity depends on the individuals who stand either at the interface of the firm and its external environment or at the interface between sub-units within the firm. Interface functions may be diffused across individuals or rather centralised. The optimal approach will be determined by the distribution of relevant expertise. Liao *et al.* (2003) state that it is critical for the firm to have both the ability to process new knowledge as well as the responsiveness to act upon it.

Communication across these links and the intermeshing of complementary functions depends on there being a sufficient level of shared knowledge and expertise. However, uniformity can result in limited scope to absorb diverse types of knowledge and result in groups that are excessively inward looking. Hence there are benefits to the firm of having diversity of knowledge structures across individuals that parallel the benefits of an individual having a diverse knowledge base. The importance of both commonality and diversity of knowledge across individuals suggests that, at the organisational level, there is a trade-off between the two. It also follows that if one or other is excessively dominant, knowledge processes will be dysfunctional.

In line with the RBV argument on the path-dependent nature of business growth and technological development, Cohen and Levinthal (*op. cit.*) argue that the development of absorptive capacity is also history/path-dependent. This results from the effective assimilation of new knowledge being dependent on accumulated prior knowledge. For example, the possession of related expertise permits a firm to assess more accurately the nature and commercial potential of technological advances. This in turn will affect the incentive to make further investments in developing capability in that domain. Therefore the development process is both cumulative and domain specific. Furthermore, if a firm has not invested in a domain of expertise early on, then it is liable to find it less attractive to invest subsequently, even if this could be a promising field because of its impact on current output. The consequence is that firms may become locked into inferior procedures, locked out of technological opportunities, exhibiting high degrees of inertia with respect to changes in their external environment. It is worth noting that although 'absorptive capacity' was initially developed by Cohen and Levinthal (*op. cit.*) in the context of innovation where outside sources of knowledge are critical, the usefulness of this concept extends to all questions relating to the identification, assimilation and application of new, external information (Bessant *et al.,* 2005).

In addition, the literature further suggests there are various factors/barriers that influence the likelihood of a firm investing sufficiently in developing its absorptive capacity. Above all, a firm is more likely to invest in capacity-enhancing activities if the knowledge domain that the firm wishes to exploit is closely related to its current knowledge base. Moreover, if a firm wishes to acquire and use knowledge unrelated to its ongoing activity, then it must dedicate resources to generating new capacity for absorbing and utilising such knowledge. On the other side, if the firm is not prepared or unable to sacrifice its current output, then it is likely to under-invest to its long-term detriment; that is to say, the firm gets locked out of certain types of knowledge if it does not acquire it early on, leading to the development of 'competency traps' whereby the firm is limited to the pursuit of a narrow set of opportunities suited to existing competencies. At a practical level, studies point to the critical role of investment in innovative assets (e.g. R&D activity) and training that firms undertake in order to absorb, assimilate and manage technologies (Cohen and Levinthal, 1989, 1990; Mowery and Rosenberg, 1989; Globerman, 2000).

Central to the application of the absorptive capacity is the issue of whether intramural and extramural R&D are complements or substitutes, since firms have the option to choose various approaches to undertaking R&D, akin to 'make' and/or 'buy' decisions, where they can undertake R&D themselves and develop their own technology (intramural R&D) and/or source externally (extramural R&D and/or licence know-how). If intramural and extramural R&D are substitutes then this is likely to have a significant impact on the amount of R&D a firm undertakes (relative to its size), especially as Cassiman and Veugelers

(1999) have proposed that small firms are more likely to restrict their R&D strategy to an exclusive make or buy choice; whereas large firms are more likely to combine both internal and external knowledge acquisition in their innovative strategy, which is linked to their absorptive capacity. That is, they find firms that generate more useful information internally are more likely to combine their internal and external sourcing strategies.

This positive impact found by Cassiman and Veugelers (*op. cit.*) of internal sourcing complementing the use of extramural R&D provides support for the absorptive capacity theory; that is, for a firm to take advantage of knowledge acquired externally, it needs to develop internally so as to facilitate a successful assimilation of the external expertise. Indeed, Veugelers (1997, p.312) argues that "cooperation in R&D has no significant effect on own R&D unless the firms have an own R&D infrastructure, in which case cooperation stimulates internal R&D expenditures…. These results support the idea that indeed absorptive capacity is necessary to be able to capitalise on the complementarities between internal and external know-how". Bonte (2003) also finds higher returns for West German manufacturing when the share of external (contracted-out) R&D rises. Notably, using data from a large-scale survey of UK, German and Irish manufacturing plants to examine business outsourcing behaviour, Love and Roper (2005) find evidence that managers/plants' strategic decisions on 'make' or 'buy' are virtually inconsistent with economists' transaction-cost reasoning. They further demonstrate that the disparities between the actual and predicted levels of outsourcing do reveal a systematic pattern, which substantiates a RBV approach to understanding firms' outsourcing strategies. Notwithstanding, there is general recognition that there are likely to be significant constraints on outsourcing R&D linked to issues surrounding absorptive capacity – if too much of a capability is outsourced it may be difficult for a firm to (re)integrate it into the firm's operations. Finally, Mowery and Rosenberg (1989) also conclude that "co-operative research programs alone are insufficient….more is needed, specifically the development of sufficient expertise within these firms to utilise the results of externally performed research".

The measuring of the firm's absorptive capacity is an important issue, which has been at the centre of the debate on its application and comparability. Above all, R&D- and patents- related variables are the most commonly deployed proxies for absorptive capacity (*c.f.* Cohen and Levinthal, 1989; 1990; Arora and Gambardella, 1990); for instance, R&D intensity (Stock *et al.*, 2001; Belderbos *et al.*, 2004), R&D stocks (Veugeler, 1997; Cassiman and Veugelers, 2002). Nevertheless, these R&D related variables suffer from serious drawbacks as absorptive capacity measures. In particular, they are frequently strongly correlated with the variable measuring innovation effort (normally the dependent variable under investigation), and thus the estimation results could be potentially biased. For example, this proxy often proves problematic when using this concept to explain why firms undertake more R&D (in order to enhance their absorptive capacity). Schmidt (2005)'s findings, for another instance, cast doubts on the validity of R&D measures – absorptive capacity is found to be path-dependent and R&D intensity does not have a significant impact on absorptive capacity.

Another frequently used measurement relates to the human capital aspect of absorptive capacity such as organisational structure and practices (Vinding, 2006); sales shares of expenditure for training of employees (Becker and Peters, 2000); and shares of highly educated employees, application of HRM practices and relationship with external bodies (Vinding, 2006). Other proxies that have featured in the empirical literature include various types of external knowledge (e.g. intra/inter-industry and scientific knowledge) as in Schmidt (2005), or from a technological catching-up viewpoint, the ratio of initial level of technology over best practice technology as in Girma (2005), etc.

Nevertheless, the literature has also acknowledged the inherent difficulty in operationalising the empirical concept of absorptive capacity, particularly due to the lack of quality micro data on the acquisition of external knowledge which constitutes a core part of the capacity. For instance, Lane *et al.* (2002) have reviewed a substantial number of articles and concluded that more work is required so as to identify firm-specific characteristics that generate such absorptive capacity. Three major limitations of this literature have been identified by Lane *et al.* (2002) as being "limited attempts to revise the definition of absorptive capacity", "little attention to the actual processes underlying absorptive capacity" and "few attempts to measure it outside of the R&D context".

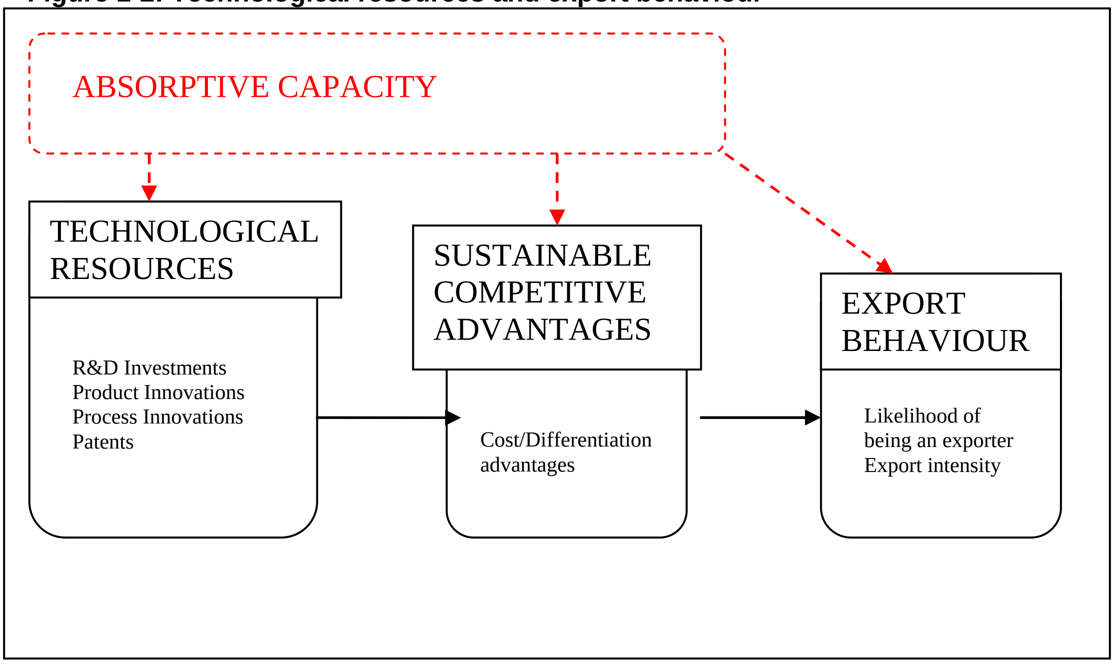
Therefore, the measurement issue is crucial when it comes to analysing absorptive capacity empirically. Quite often it is required to be measured in more specific ways, and this problem is dealt with in Chapter 3 which examines the impact of absorptive capacity in determining R&D and exporting activities. Indeed, as a major methodological contribution of this thesis to the literature on absorptive capacity, a factor analysis is deployed to extract information based on dozens of variables relating to the establishment's intake of knowledge. As Chapter 3 shows, for the first time, it is possible to capture various dimensions to the absorptive capacity, including the most process-oriented dimensions that were not measurable, such as the capabilities of assimilating and applying external knowledge from diverse sources.

1.3 Exporting from an RBV Perspective

Engagement in exporting activity (and international trade in general) is generally perceived as beneficial to individual firms and the economy as a whole. Consequently the volume of international commerce has been surging dramatically within last two decades, partly encouraged by deregulation, such as the abolition of exchange controls, as well as the easing of trade restrictions through both WTO and regional institutions like the European Community. The advantages associated with going international are varied, as pointed out by Bernard and Jensen (1999), including faster growth of shipments and productivity, diversification of risk, increased innovation, better investment opportunities leading to improved survival prospects and gains for workers in terms of higher pay and better future work opportunities. Nevertheless, in essence, the pursuit of firm-specific resources constitutes the principle stimuli of a firm's decision to invest in international markets. For instance, on the international stage, these distinctive firm-specific resources include technological opportunities, brand names, export contacts, coordinated relationships with suppliers and clients, superior marketing and managerial skills and thus the capacity to exploit economics of scale. From an RBV perspective, these advantages conferred by resources and capacities can greatly enhance firms' international competitiveness and consequently bring about higher rate of return and profitability, particularly in global markets characterised by a variety of market imperfections such as asymmetric information, capital immobility and so on.

Following the discussion in Chapter 1 (pp.4-17) on the role of knowledge and resources – in the firm's innovative behaviour in particular and development and growth in general – in an open economy, one can expect this role to be particularly crucial in the growth of exporting firms in that there is a stronger need for them to acquire, apprehend and assimilate new knowledge/information in order to compete and grow in global markets where they have little or no previous experience. Drawing on the literature on internationalisation in general and/or exporting in particular, this section reviews the process of firms' going international and most importantly, the critical role played in this process by knowledge, resources and capacities; and therefore, the terms 'exporting' and 'internationalising' are frequently used interchangeably[3].

Figure 1-2: Technological resources and export behaviour



Source: expanded version of Lopez Rodriguez and Garcia Rodriguez (2005).

When a firm internationalises, it must absorb completely new knowledge of how to organise for foreign competition, thus facing the dual challenge of overcoming rigidities and taking on novel knowledge. In this sense, one could expect the development of absorptive capacity to be a necessary condition for

[3] Note other forms of 'internationalisation' are not explicitly discussed here (e.g. inward/outward FDI), although these might be touched upon at times for the purpose of comparison, as these are beyond the scope of this thesis.

the successful exploitation of new knowledge gained in global markets. Lopez Rodriguez and Garcia Rodriguez (2005) propose a conceptual model (see Figure 1-2) to explain how technological resources impact upon a firm's export behaviour through conferring cost/product differentiation advantages. This model can be extended to include the notion of absorptive capacity (in Figure 1-2) – as it provides the firm with the ability to internalise new knowledge gained in global markets – and the development of absorptive capacity could be expected to be a necessary condition for the materialisation of all these stages depicted in this model.

The area of international entrepreneurship has been well-researched in the recent business and management literature, which offers various conceptual models with intuitive approaches to explaining the phenomenon of internationalisation, from the traditional incremental models, the more recent early-internationalisation models, to the models of internationalisation from a resource-based perspective.

1.3.1 Traditional Incremental Models

Traditional models (e.g. the Uppsala model of the evolutionary development of globalising firms) consider internationalisation as incremental, and crucially determined by the speed and ability to accumulate knowledge through exposure to overseas markets. Additional costs and uncertainties are faced when entering a new foreign environment, although this literature is more concerned with explaining which processes are important in explaining how such potential barriers are overcome. As such, these models offer a less quantitative and more descriptive (often case study) approach to describing the role of knowledge accumulation in countering barriers to internationalisation.

Now recall the earlier discussion on the factors that influence business investment in the development of absorptive capacity (p.14), with one of the factors being the need to acquire and exploit knowledge unrelated to its ongoing activity. This argument parallels the process/stage models of internationalisation, where experiential knowledge of a foreign market is linked to increased speed of commitment to the market (Johanson and Vahlne, 1990). Furthermore, it can be hypothesised (Autio *et al.*, 2000) that the firm's age at first entry into export markets will affect how quickly it will gain new foreign knowledge (and how likely it will be to favour continued international expansion as a growth strategy). That is, firms that internationalise at a later age are likely to have developed competencies constraining what they see and how they see it. Autio *et al.* (*op. cit.*) find strong evidence that the age of a high-tech firm at international entry is negatively related to its subsequent growth in international sales, and that the knowledge intensity of such firms is positively related to their growth in international sales. In all, these results are in support of the RBV and knowledge-based views of international expansion, and especially support for the concept of "learning advantages of newness". This is consistent with the earlier work of Brush and Vanderwerf (1992) who find that early internationalising firms hold more positive attitudes towards foreign markets than those that internationalise late.

Much of the early research on internationalisation is based on extensive empirical research that observes most firms entering foreign markets do so in an incremental fashion, by building up resources before proceeding beyond markets 'close to home' (i.e. 'psychically close' because competitors also operate there and/or 'cultural' barriers are lower). Thus, larger firms (which are likely to be older and in possession of more resources) have high probability to build up their presence in domestic markets before entering first export markets.

Typical theoretical models developed in this respect can be best represented by the traditional process/stage model, which consider internationalisation as an incremental process and based on a risk-averse and reluctant adjustment to changes in a firm or its environment (*c.f.* Johanson and Vahlne, 1977; 1990). Initially firms operate in the vicinity of their existing knowledge and supply only to domestic markets unless provoked, pushed, or pulled by events such as unsolicited export orders or adverse conditions in the home market. Once initiated, internationalisation starts in markets with the lowest uncertainty and risk (i.e. those 'close to home' markets), with an entry mode that requires relatively few resources (e.g. exporting vis-à-vis other forms of going global). The speed and ability to accumulate knowledge through exposure to overseas markets then determine subsequent pace of internationalisation, as it positively feeds back to decisions to commit resources for future activities in foreign markets. So, typically, firms internationalise one market at a time and concentrate on a small number of key markets, adapting their existing goods and services to the needs of each new market (Bell *et al.*, 2003).

This process is seen as being reactive with little use of strategic choices when increasing exposure to overseas markets; indeed internationalisation proceeds irrespective of whether or not strategic decisions are taken by the management (Johanson and Vahlne, 1990) and this deterministic aspect of the model is an important (and often criticised) feature of the model (*c.f.* Andersen, 1993; McDougall *et al.*, 1994; Bell, 1995; Oviatt and McDougall, 1997). In this traditional approach, the main goals of the firm are described as ensuring survival through increasing sales volume, greater market share and/or extending product life cycles.

Despite criticisms of the process/stages model outlined above, there is empirical evidence that many firms do indeed internationalise in incremental stages, firstly by entering those foreign markets that are most similar to their home market (*c.f*. Cavusgil, 1980; Reid, 1981; Lim *et al.*, 1991; Crick, 1995; Bürge and Murray, 2000). They also tend to increase the level of commitment and resources over time as internationalisation proceeds in stages. Much of the recent criticism of the process model comes from recent evidence of the 'born-global' firms (see pp. 22-26) which enter foreign markets at a time (and in a manner) that appears inconsistent with the notion of incremental stages of internationalisation. However, if due emphasis is placed upon the role and importance of the accumulation of knowledge for internationalisation and the availability of complementary resources and absorptive capabilities, then the process model simply states that those firms that lack the means and the relevant conditions for rapid internationalisation will be best served by proceeding in a more cautious and incremental fashion. As Eriksson *et al.* (1997, p. 353) state

> …in internationalising, a firm must develop structures and routines that are compatible with its internal resources and competence, and that can guide the search for experiential knowledge about foreign markets and institutions.

This simply points to the need to extend the process model of internationalisation to include other perspectives that incorporate theories of the RBV, organisational capability, knowledge and/or learning-based views (e.g. Madsen and Servais, 1997; Autio *et al.*, 2000; Zahra *et al.*, 2003).

1.3.2 Early Internationalisation/'Born-Global' Models

Nevertheless, recent literature has documented evidence on rather different export behaviour drawing on far more rapid internationalisation in the last decade, challenging the traditional view of internationalisation developing in incremental stages. Put another way, there is no longer a need for such (often smaller) firms to build a stable domestic position before going onto the international stage; rather, they globalise right from their birth by exporting directly international markets or forming joint ventures to penetrate foreign markets even without any prior experience. Therefore, some argue that this theory of early internationalisation or 'born-global' firms is inconsistent with the process models, with an emphasis on the formation of new ventures capable of competing in foreign markets almost from near inception (*c.f.* McDougall *et al.*, 1994; Bell, 1995; Roberts and Senturia, 1996; Oviatt and McDougall, 1997; Shrader *et al.*, 2000; Moen and Servais, 2002).

Nevertheless, a closer look reveals that the underlying fundamentals do not seem to differ between these two strands of literature: the 'born-global' phenomenon is equally substantiated by the crucial significance of resources and capabilities (especially absorptive capacity); for instance, the role of joint-ventures could be perceived as a means of overcoming initial resource and competency gaps (i.e. sunk entry costs), since such firms may not possess prior experience nor have the time to integrate prior knowledge and fully develop their international strategies before implementing them. It follows that this area of the literature often concentrates on particular sub-groups of firms such as high-tech small and medium enterprises (henceforth SMEs) (Jolly *et al.*, 1992), international new ventures (Oviatt and McDougall, 1994), and attempts to provide alternative (more eclectic) explanations for the development of globalisation of these businesses − the importance and role of networks and the use of inter-personal relationships (Harris and Wheeler, 2005); the importance of individuals in the firm with prior exposure to international markets; the role of 'serendipity' (or 'luck') (Crick and Spence, 2005); and lastly, from a cognitive perspective, the managerial capacity (or human capital) for recognising and exploiting opportunities in international markets (Zahra *et al.*, 2005).

From an economic perspective, at an aggregate level, early internationalisation of firms have been made possible largely due to increased importance of globalisation, which can be associated with: 1) new market conditions in many sectors of economic activity (including the increasing importance of niche markets for SMEs worldwide); 2) technological developments in the areas of production, transportation and communication, leading to significant reductions in the costs associated with internationalisation as well as the rising importance of knowledge-based technologies [4]; 3) the increased importance of global networks and alliances, which provide easier and better access to knowledge [5]; and 4) more elaborate capabilities of people, particularly of the founder/entrepreneur (*c.f.* Madsen and Servais, 1997).

Thus on the 'push' side of this phenomenon, many new ventures that go international seem to be in high-tech industries that may require some international sales as a condition of industry participation given the specialised global-market niches served by such firms (McDougall *et al.,* 1994; Bryan *et al.*, 1999). Thus sales to domestic markets alone would not be sufficient to cover the initial sunk costs of market entry, given the technological requirements that firms commit to high R&D expenditures and product innovation (or similar investments in new technology). Thus where technological change is rapid, short product cycles may naturally lead to increased internationalisation (*c.f.* the product life cycle model as in Vernon, 1966).

On the 'pull' side, in many sectors of economic activity there has been growing demand for goods and services with greater commitment to differentiation and quality (i.e. the establishment of 'niches'), offering firms that can differentiate themselves from indigenous foreign competitors the opportunity to derive strong

[4] With recent advances in modern communication infrastructures (e.g. the internet) information once it is produced is now more mobile and can be reproduced and transported very quickly at little marginal cost. Knowledge can thus be combined with less mobile resources in multiple countries. Thus, knowledge-intensive industries have been globalising quickly, and it becomes easier for new ventures with valuable knowledge to internationalise sooner.

[5] As Hedlund and Kverneland (1985) argue, the increasing homogenisation of many markets in distant countries has made the conduct of international business easier to understand for all involved.

sales from a foreign market. Such firms are often smaller SMEs rather than the traditionally larger firms that gradually internationalise incrementally. Moreover, a dramatically increasing number of people (including business executives and entrepreneurs) have gained international experience during recent decades, with associated mobility across nations (Johnston, 1991), languages and cultures, and thus with enhanced capabilities on offer to firms involved in (early) internationalisation (Madsen and Servais, 1997).

Needless to say, at the micro level, the phenomenon of early internationalisation is also driven by heterogeneous firm-level characteristics; that is, 'born-global' exporters do not constitute a random group. These distinctive firm-specific factors, mostly related to early internationalisation, are summarised in Rialp *et al.* (2005, p. 160), based on the results from existing literature (not necessarily in any order of importance): for instance, high degree of previous international experience on behalf of managers; a managerial global vision from inception; management commitment; strong use of personal and business networks (networking); market knowledge and market commitment; unique intangible assets based on knowledge management; high value creation through product differentiation; production of leading-edge technologies; technological innovativeness with a strength in IT use; quality leadership; a niche-focused, proactive international strategy in geographically spread markets; narrowly defined customer groups with strong customer orientation and close customer relationships; and, finally, flexibility to adapt to rapidly changing external conditions and circumstances.

In another attempt to identify the heterogeneous characteristics associated with early internationalising firms, a large-scale panel study by Bürgel *et al.* (2004) examines over 2,000 firms in high-tech industries in Britain and Germany. Mostly in accordance with Rialp *et al.* (2005), their results provide useful insights into the following aspects – while most firms remain small (only one fifth of all firms growing to over 20 FTE employees), firm size is of great importance in determining the degree of internationalisation; older firms are more likely to internationalise; R&D (and its persistent use) is extremely important for internationalisation activities, confirming the role played by absorptive capacity; novel technology embraced in products confers firms advantages in the process of internationalisation; lastly, the prior international experience of managers as well as the industrial sector that a firm belongs to also matter.

In addition to the studies reviewed above, the evidence (mostly drawing from the business and management literature) on what engenders the process of early internationalisation comprises a number of (mostly) qualitative/case-study based papers and some quantitative/survey-based studies (mostly cross-sectional). For instance, the case-study literature includes papers such as Jolly *et al.* (1992); McDougall *et al.* (1994); Boter and Holmquist (1996); Roberts and Senturia (1996) and Sharma and Blomstermo (2003). The preponderance of the literature on early internationalisation comprises of survey-based studies, such as Bell (1995); Reuber and Fischer (1997); Bürgel and Murray (2000); Knight (2000); and Zahra *et al.* (2003). There are also a number of studies based on the analysis of panel data, for example, Bloodgood *et al.* (1996); McDougall and Oviatt (1996); Autio *et al.* (2000); and Shrader *et al.* (2000), to name just a few.

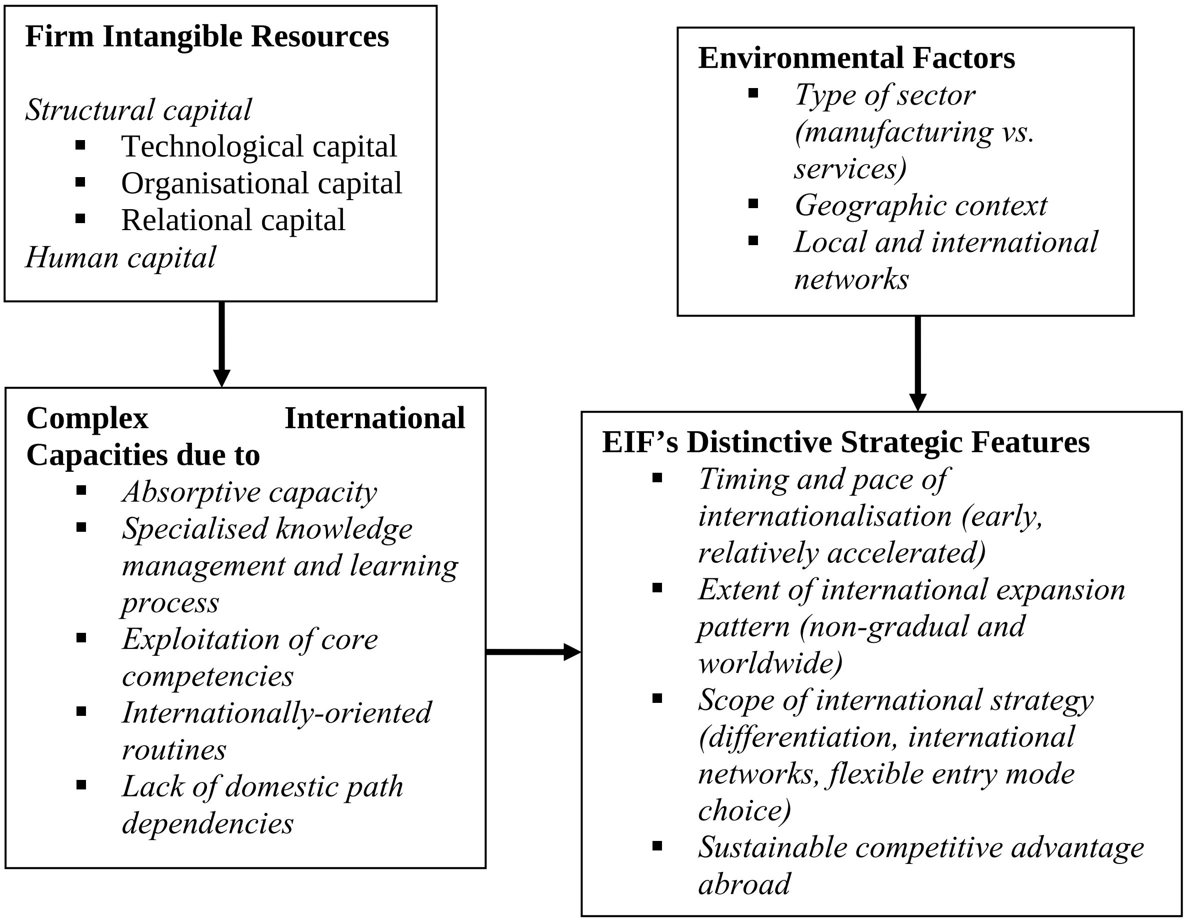
To summarise, various issues have been flagged up in this literature of early internationalisation, such as whether this phenomenon is new and highly sector-specific, with particular implication for public-sector involvement in facilitating internationalisation; whether it will become more important over time (alongside increasing globalisation). Several authors argue that early internationalisation is better suited to smaller knowledge-intensive firms (where technological intensiveness pervades) (e.g. Autio and Sapienza, 2000; Bell *et al.*, 2003; Sharma and Blomstermo, 2003). Nevertheless, others have revealed that this phenomenon is not necessarily limited to just new, high-tech sector firms (e.g. Moen and Servais, 2002). Indeed Bell *et al.* (2003) argue that early internationalising firms can be further classified as being either ‘knowledge- and/or service-intensive’ or ‘knowledge-based’. The latter relates more to the emergence of new technologies (IT, biotechnology, etc.), involving developed proprietary knowledge or acquired knowledge without which they would not exist, and thus is by definition limited to certain high-tech sectors. In contrast, knowledge intensive firms use knowledge to develop new offerings, improve productivity, introduce new methods of production and/or improve service delivery (e.g. CAD/CAM/JIT), and it is argued that such firms are going to continue to become increasingly important across more sectors and in more countries, challenging further the traditional incremental approach to internationalisation.

1.3.3 Conceptual RBV Models

From a resource-based perspective, in essence, both types of models reviewed above are substantiated by the underlying assumption of the importance of resources and capabilities, as crucial factors determining the process of business internationalisation. Therefore, this section highlights the RBV component underlying these models of firm globalisation (in this more business-and-management oriented literature), by reviewing some recent models of internationalisation (many of which have been developed for mostly the 'born-global' phenomenon).

An early and simplified model developed by Bloodgood *et al.* (1996) posits that internationalisation is determined by firm size, innovation, various sources of competitive advantage (e.g. low cost strategies, product/marketing differentiation) and the extent to which top management has had international exposure. More illustratively, Bell *et al.* (2003, Figure 1) provide an integrated model of internationalisation, which has at its core the extent to which sources of competitive advantage (with knowledge being the leading source) can explain various forms of internationalisation (i.e. the traditional, 'born-global' and 'born-again-global' pathways) as well as its pace. This conceptual model further suggests that the more sophisticated the knowledge base, the higher the probability of a firm internationalising early and more rapidly than firms with more basic capabilities. Most importantly, the originators of the model also recognise that several theories are relevant to explaining internationalisation, and thus the model incorporates dimensions of extant incremental 'stage' theories and network perspectives, whilst recognising the importance of RBV and contingency approaches.

Figure 1-3: An adaptation of Rialp *et al.*'s model of the Early Internationalising Firm (EIF)



Source: Rialp *et al.* (2005)

In an extensive review of the literature on early internationalising firms, Rialp *et al.* (2005) have also produced a model applying the RBV approach to internationalisation (see the adaptation of this in Figure 1-3 above). As argued by the authors, this model shows that a firm's intangible resource base (e.g. organizational, technological, relational and human capital resources) may be of the highest importance in generating a critical level of capability of internationalization. Secondly, firm-specific international capability can be regarded as an unobservable or 'invisible' strategic asset mostly characterised by scarce home-based path dependencies, with high levels of tacitness and causal ambiguity in its accumulation process. Essentially, it is the result of mixing primarily intangible resources in such a way that generates complex interactions amongst them as well as internationally intensive routines through which all the firm's resources are coordinated (*c.f.* Grant, 1991). Lastly, it is worth noting that the external environmental factors (e.g. industrial sector, geographic setting and interconnected home and international networks) may also play a crucial role in moderating the way in which intangible resources contribute to the development of both the strategic behaviour of early internationalising firms and their sustainable competitive advantages abroad.

1.3.4 Economics Models of Internationalisation

The development of economic models to explain internationalisation is merely seen in more recent economics literature (as opposed to the earlier discussion of this phenomenon that prevails in business and management literature). Such (theoretical) models have been developed initially only to encompass and explain certain firm-level empirical facts that have been observed in recent years (e.g. from the pioneering work of Bernard and Jensen, 1995, 1999) − 1) exporting is concentrated amongst a very small number of firms who nevertheless are large and account for the preponderance of trade undertaken (Bernard *et al.*, 2005); 2) compared with non-exporting indigenous firms, such exporters, *cet. par.*, have a greater probability of survival, much higher growth, are more productive, more capital-intensive, pay higher wages, employ better technology and more skilled personnel. The review of economics literature on firm internationalisation here will in particular, help motivate the issues addressed in Chapters 3 and 5 in light of the determinants of exporting, with its emphases on sunk costs and firm-level heterogeneity.

The economics literature explaining when and how certain firms internationalise can be linked to early theories of monopolistic advantage (e.g. Hymer, 1976) and more recently the RBV of the firm and its emphasis on organisational capabilities as a determinant of organisational outcomes (e.g. Barney, 1991; Kogut and Zander, 1996; Teece *el. al.*, 1997). As discussed at the beginning of this chapter (pp.1-4), the firm's monopolistic advantage is associated with the generation of higher 'Ricardian' rents exploiting firm-specific assets that cannot be replicated by other firms. In the context of international trade, this implies despite the fact that local firms nearly always enjoy certain advantages over their foreign competitors (e.g. greater knowledge of the culture and a superior network of local business partners), firms that go international possess intangible productive assets that could be utilised to give them a competitive advantage (Hymer, *op. cit.*). These firm-specific intangible assets include specialised know-how about exports production and related cost advantages, extensive international contacts and networks and so forth.

This literature explores the drivers and process of internationalisation with special emphases placed upon the role of transport costs, the different relative sunk (entry) costs of various modes of market access, and the key role played by firm heterogeneity that leads to productivity differences between firms (e.g. Helpman *et al.*, 2004). In addition, a number of studies in this area investigate the firm's going global in a setting of comparison between exporting and foreign direct investment (henceforth FDI), which seeks to explain whether these two strategies of international expansion are alternatives or complements (e.g. Head and Ries, 2004), given that statistical evidence seems to suggest that exporting and FDI are positively correlated even though economic theory suggests such activities are usually substitutes.

In particular, the more recent economics literature highlights the importance of sunk costs and firm heterogeneity as determinants of internationalisation. Following the theoretical literature on sunk costs and exporting (initially developed by Dixit, 1989; Baldwin, 1988; and Baldwin and Krugman, 1989), Bernard and Jensen (2004a) model the decision to export allowing for firms to have different characteristics (which impact on their profitability[6]) and for them to face (sunk) entry costs into foreign markets[7]. The latter potentially include the cost of information about demand conditions abroad (e.g. market research), or the cost of establishing a distribution system, or the need to modify products for different markets and to comply with institutional arrangements and regulations (including differences in the 'culture' of the way business is carried out). It is also assumed that such non-recoverable entry costs recur in full if the firm exits the export market for any amount of time.

Ultimately, firms only internationalise if the present value of their profits (affected by their characteristics) exceeds these fixed costs of entry. Moreover,

[6] These include size, labour composition, productivity, product mix and ownership structure.

[7] They also recognised that other exogenous factors affect profitability and thus the decision to export or not, such as exchange rate movements, other shocks to demand, indirect and direct subsidies to exporters and potential spillovers from the presence of other nearby exporters. However, it is firm heterogeneity and sunk costs that dominate (especially in empirical applications of this type of model – see below).

this study also examines whether firm entry into export markets (and continuing to export with/without increasing export intensity) is due to certain plants being more export-orientated because of their attributes and/or because of the presence of sunk costs. In principle, Bernard and Jensen's model can differentiate between the competing determinants of exporting; nevertheless, in practice the proxy used in empirical work for measuring sunk costs is usually less well defined and unobserved plant heterogeneity has to be accounted for which can also contaminate the empirical proxy used to measure sunk costs. Their results suggest that, in line with expectations, both heterogeneity and sunk costs are found to be important determinants of internationalisation.

More recently, Helpman *et al.* (2004) develop a model with similar features to the Bernard-Jensen approach. Assuming monopolistic competition, firms exogenously differ in their levels of productivity (as captured by differences in the marginal costs of production); they produce a differentiated good; consumers have standard Dixit-Stiglitz preferences; and different modes of market entry (exporting versus FDI in foreign markets) have different relative costs (some of which are sunk entry costs while others vary with output such as transport costs and tariffs). Thus this model not only determines which firms internationalise, but also the mode of entry. Firms choose FDI over exporting if the benefits from avoiding transportation costs exceed the fixed costs of establishing capacity in a foreign market (i.e. when transport costs are relatively high and when plant-level returns to scale are relatively weak). Their model is able to show that the least productive firms do not internationalise (and indeed the worst exit the industry), and of those that do only the most productive engage in FDI, while firms with intermediate productivity levels export. Thus, the extent of intra-industry firm heterogeneity plays a key role in determining the volume of FDI sales relative to the volume of exports, and thus the composition of trade.

Head and Ries (2003) also consider differences in firm productivity as an explanation of different modes of foreign-market entry. Their model (Figure 1) shows that for firms with very low productivity levels neither exporting nor FDI is profitable. In terms of firms that internationalise, since there are additional (higher) fixed costs of establishing a foreign plant through FDI the profit-productivity relationship for firms using FDI as their mode of entry is lower, but as productivity increases FDI profits rise more rapidly than exporting profits[8]. Therefore this model predicts the co-existence of firms that conduct FDI and firms that export within the same industry.

This model can also be used to show why an individual firm might engage simultaneously in both exporting and FDI; if fixed costs differ between different markets, a firm will export to the high-fixed-cost market and carry out FDI in the low-fixed-cost market. Thus, trade costs are positively related to FDI but negatively related to exports, whereas fixed sunk costs are positively related to exports but negatively related to FDI. As Head and Ries (2004) point out, the empirical evidence confirms the sorting of plants by productivity into those that do not internationalise (with the lowest levels of productivity) through to those that engage in exporting (with medium levels of productivity) and those in FDI (with the highest productivity).

Others have examined the link between tariff reduction and plant-level internationalisation using similar approaches, which show that only the most productive plants enter the export market to overcome trade barriers (Bernard *et al.* 2003; Melitz, 2003; Baldwin and Gu, 2004). As barriers fall, export intensity rises and (the most productive) non-exporters now internationalise (since production costs fall as imports become cheaper and competitiveness rises with lower tariffs). Evidence is documented in Baldwin and Gu (*op. cit.*) who consider the impact of tariff reduction on Canadian manufacturing between 1984-1996. Their results show that cuts in tariffs both increase the probability of internationalising for all plants and more particularly for those with the highest levels of relative labour productivity. The results also show that larger, younger and more productive plants are more likely to export.

Further empirical evidence on the factors that determine whether firms internationalise is provided in Bernard and Jensen (2004a) for the US and Greenaway and Kneller (2004) for the UK[9]. Lagged export status (i.e. whether the plant exported in the previous period) is used as a proxy for sunk costs, and is always highly significant as a determinant of exporting. Bernard and Jensen's

8 Comparative production costs in domestic and foreign markets (particularly trade costs) determine the slope of the profitability-productivity relationship.

9 More evidence of a similar nature is surveyed in Chapter 4.

findings show that exporting last year raised the probability of exporting this year by 66% in the US; but when they allow for fixed effects to incorporate plant-level heterogeneity, the effect declined to 20%. Greenaway and Kneller's results for the UK show that the impact was 83%, which seems improbably high[10].

Bernard and Jensen (*op. cit.*) for the US also find that spillover effects are not present, and that state export promotion has a slightly positive effect (but statistically insignificant). However, size, wage (representing human-capital intensity) and productivity have important influences on the probability of exporting, with larger, productive plants being much more likely to export. Greenaway and Kneller (*op. cit.*) for the UK find similar results, although the impact of total factor productivity (henceforth TFP) on the probability of exporting is not statistically significant, while industry agglomeration effects (associated with spillovers) are important in the case of the UK[11].

To summarise, those firms that export tend to be a non-random sample of all businesses in that they are typically larger, more productive and have the capabilities/resources to overcome sunk fixed costs associated with entering foreign markets. This has implications for the discussion in Chapter 4 (and the empirical modelling part in Chapter 5, i.e. pp.203-230) on the issue of whether 'better' plants self-select into exporting and/or whether there is any evidence that plants become more productive over time through a 'learning-by-exporting' effect.

[10] Presumably this result is biased upwards due to an inability to account for unobserved plant-level characteristics

[11] Other studies for the UK using panel data provide similar results, confirming the importance of sunk costs and productivity, but also the role of resources, innovation and human-capital factors that all positively impact on the decision to export (*c.f.* Wakelin, 1998; Bleaney and Wakelin, 2002; Roper and Love, 2002; and Gourlay and Seaton, 2004).

Chapter 2: The Determinants of Exporting and Innovating Activities and Their Inter-Relationship

2.1 Major Determinants of Exporting in the Literature

The literature on trade has documented the predominant role that productivity plays in facilitating the firm's entry into international markets (see the discussion relating to the 'self-selection' hypothesis in Chapter 4, pp.155-156). In addition to this crucial driver in terms of productivity, to get a more holistic view, this part examines some other factors affecting the firm's export orientation. This will also help to put the important export-productivity relationship into context (in advance of the extensive discussion in Chapter 4), and explain the underlying resources for such a relationship.

It is important to note that, as evidenced in the subsequent empirical analysis of the determinants of exporting (*c.f.* Chapter 3), there normally exist two distinct exporting decisions, viz. whether to export or not (i.e. export propensity) and how much to export conditional on entering export markets (i.e. export per unit of sales or export intensity). Thus, some of the variables that are discussed below may feature in only one of the decision-making processes and/or the impact may differ between two decisions.

2.1.1 Innovation

First and foremost, innovation is generally perceived as the major driving force behind exporting in conventional trade theories (*c.f.* Vernon, 1966; Krugman, 1979)[12]. From a firm's perspective, exporters need to invest in R&D and training to develop internally by absorbing, assimilating and managing technologies and ideas obtained from foreign markets. Innovation facilitates a firm's competency development and brings about scale and scope economies. The resulting greater production efficiency enables firms to expand their domestic market shares

[12] Also the last section of this chapter, pp.59-69, provides a thorough evaluation of the export-innovation inter-linkage.

through import substitution, and most importantly, to penetrate new foreign markets and increase their exports shares[13].

This may help to explain how differences in productivity affect export-market participation as observed in heterogeneous firms, industries and countries[14], in line with the notion of absorptive capacity and the crucial role of R&D in developing such capacity, thereby allowing firms to internalise external knowledge (Cohen and Levinthal, 1989, 1990).

Empirically, a variety of innovation-related variables have been conventionally included in the modelling of export behaviour, such as R&D dummies indicating whether or not a firm is an innovator; R&D intensity; patents; formal R&D expenditures; the value of the licensing fees and royalties abroad; dummies that distinguish between the producers of capital goods and other types of goods; skills and the capital intensity of operations; imports of technology; number of innovation used/generated either in the firm or industry to which the firm belongs and the alike. In terms of findings, Bleaney and Wakelin (2002) and Roper and Love (2002) have reported significant differences in terms of R&D expenditures at plant level between exporters and non-exporters in the UK manufacturing, and thus the moderating effect of innovation on the export-productivity nexus; similar findings are also suggested for Canada (Baldwin and Gu, 2004). In particular, Baldwin and Gu (2004) make use of data for Canadian manufacturers to test whether exporters have higher levels of R&D. Their results show that (after controlling for other relevant covariates such as size) undertaking R&D is 10% higher for exporters vis-à-vis non-exporters (but there is no statistically significant differential in favour of exporters prior to their internationalisation). Thus, they show some evidence for increased innovation activity after internationalising, which is consistent with their argument that benefits from export-market entry are not 'automatic' – in order to achieve post-entry productivity gains, exporters invest more in R&D and human capital to acquire more foreign technologies and enhance absorptive capacities.

[13] Note, firms that export usually only sell a small proportion of their output in foreign markets. Therefore when they expand due to efficiency gains, they can capture additional shares in both domestic and foreign markets.

[14] See Aw *et al.* (2000) for a comparative study between Taiwan and South Korea.

2.1.2 Absorptive Capacity

The importance of absorptive capacity in determining the firm's exporting activity is at the heart of issues addressed in this thesis. When setting out the overall theoretical background from an RBV perspective, the crucial role played by absorptive capacity has been discussed in Chapter 1 (pp.17-32).

2.1.3 Sector Effect

As industries are not homogeneous in their exporting patterns, the sector effect (reflecting technological opportunity and product cycle differences) is usually expected to be significant. A general approach often employed in the literature is to categorise firms into different sectors according to levels of technology intensity, which is often measured by the ratio of R&D expenditure to total sales. Numerous empirical studies show that significant differentiated industrial patterns condition a firm's strategy of internationalisation (for instance, Hirsch and Bijaoui, 1985; Hughes, 1986; Soete, 1987; Bleaney and Wakelin, 2002; Gourlay and Seaton, 2004 and Lopez Rodriguez and Garcia Rodriguez, 2005).

As far as the UK is concerned, Bleaney and Wakelin (2002) find that firms are much more likely to export if they are located in a sector with a high level of R&D intensity. Gourlay and Seaton (2004a) point out that more research intensive and diversified firms with a larger resource base and more skilled workers are more likely to export; however, this pattern varies across industries as some industries might compete on labour costs rather than product quality and design. Interestingly, in the context of Spanish manufacturing, Lopez Rodriguez and Garcia Rodriguez (2005) show that belonging to a technology-intensive sector has an insignificant effect on the decision to export, although this impact is significantly positive with regard to export intensity. Their interpretation of this finding is that the decision to enter export markets only depends on the firm's internal characteristics (e.g. technological capabilities) that determine its degree of competitiveness, but not the sector to which the firm belongs. The fact that a firm belongs to a technology-intensive industry does not guarantee its superior capacity to overcome barriers and gain access to international markets, if it is not equipped with the competitive advantage to allow it to compete at global level (and thus, sectors do not seem to matter much at this initial stage). Nevertheless, once the firm has successfully entered an international market, being in a sector that is technologically intensive increases its export intensity, possibly due to technological spillovers, knowledge transfers, externalities and accumulated experience within that industry, which allow the improvement of technological capacity within the firm *per se*. As a result of this learning process, the enhanced competence base will bring about increased competitiveness, which will then positively impact on export intensity in turn.

As such, there are important implications for policy, calling for the recognition of distinctions between policies designed to increase the export penetration of domestic firms into new markets and those formulated to extend existing foreign-market penetration. In particular, such policies for export promotion[15] need to be industry-specific, as there are sectoral differences between entering new and existing markets.

2.1.4 Industrial/Spatial Agglomeration

Others concentrate on the role of certain structural factors in increasing the probability of export-market entry. For instance, the importance of geographic factors is captured in Overman *et al.*'s (2003) survey of the literature on the economic geography of trade flows and the location of production. If information on foreign-market opportunities and costs is asymmetric, then it is reasonable to expect firms to cluster within the same industry/region so as to achieve information sharing and therefore minimise entry costs. Co-location may help improve information about foreign markets and tastes so as to provide better channels through which firms distribute their goods (Aitken *et al.*, 1997). There are usually two dimensions to these agglomeration effects – a regional effect and an industrial effect. The former comprises the spatial concentration of exporters (from various industries); whereas the industry effect stems from the fact that exporting firms from the same industry co-locate. Greenaway and Kneller (2004) provide empirical evidence that shows the industrial dimension of agglomeration

[15] Here this refers to promoting entry into export markets, not subsidising export volumes, which are distortionary.

would appear to be more important for the UK, while Bernard and Jensen (2004a) find it to be insignificant in explaining the probability of exporting in the US. The benefits brought about by the co-location of firms on the export decision have also been documented in other empirical studies, such as Aitken *et al.* (1997) for Mexico[16].

2.1.5 Market Concentration

In a similar way, market concentration is also expected to positively impact upon a firm's propensity to export and its performance post entry. Above all, a more concentrated market may imply higher profits available, suggesting that more firms will be able to meet the costs of participating in international markets. Furthermore, a high level of concentration of exporters within an industry may improve the underlying infrastructure that is necessary to facilitate access to international markets or to access information on the demand characteristics of foreign consumers. Therefore, non-participants might be expected to have a higher propensity to go international in a market with a higher degree of concentration of export activity. Evidence for UK manufacturing covering the 1988-2002 period is provided in Greenaway and Kneller (2008).

2.1.6 Export Spillovers

Going hand in hand with these location effects is the impact of export spillovers; that is, knowledge spillovers from foreign firms impact on the export decision of domestic firms. These spillovers take place if there is a transfer of knowledge from foreign markets to domestic firms. This linkage of knowledge between international markets and domestic firms is derived from the literature on international knowledge diffusion. International trade is argued to be a conduit for the transfer of knowledge and thus conducive to productivity growth (Grossman and Helpman, 1991). From a firm's perspective, participation in international markets brings it into contact with international best practices and

[16] Bernard and Jensen (2004a) find negligible spillovers resulting from the export activity of other plants; nevertheless, this disparate finding may be explained by the authors' sample selection criteria (i.e. restrained to large plants only) and measurements of industry (i.e. at 2 digit level) and regions (i.e. at aggregate state level).

facilitates its activities of learning and competency development. Following Coe and Helpman's (1995) seminal piece on international spillovers (mostly in the form of R&D spillovers), there has been an increasing interest on the impact of international technology spillovers (e.g. Jaffe and Trajtenberg, 1998; Eaton and Kortum, 1999; Frantzen, 2000). It is widely felt that such spillovers provide positive information externalities (Aitken *et al.*, 1997), and as public goods, these knowledge spillovers can help domestic recipients to achieve higher technological standards with less effort.

The positive effect of export spillovers results from both supply- and demand-side impacts. The supply-side argument is derived from the existence of sunk entry costs as discussed at the end of Chapter 1 (pp.28-32). Export-market entry costs arise as a result of imperfect information in firms' process of establishing foreign marketing channels, learning bureaucratic procedures, developing new packaging/product varieties and so on. By their very nature, information spillovers can significantly reduce any problems of information asymmetry and therefore lower start-up costs, so pushing rational firms to enter export markets when the present value of their anticipated profits exceeds current fixed costs. In contrast, there may also be a demand-side impact associated with export spillovers: following the establishment of a presence in overseas market, foreign awareness of (and thus demand for) domestically produced goods may also rise, pulling more domestic firms into export markets.

In addition, Kneller and Pisu (2007) examine the role of FDI industrial linkages in explaining export activity at the firm-level. They find that the decision to enter an export market is positively related to the presence of foreign plants in the same industry and region; the decision concerning how much to export is affected positively by the presence of foreign firms in downstream industries. In another study using a large panel of UK firms, Greenaway *et al.* (2004) also find evidence of positive spillover effects from multinational enterprises (MNEs) on the decision to export of domestic (UK) firms, and on their export propensity.

2.1.7 International Outsourcing

Finally, recent years have seen a growing interest in the literature of the impact of international outsourcing on productivity in globalised firms. From an RBV perspective, the rationale for expecting a positive effect from outsourcing in international markets is consistent with the notion of learning and absorptive capacity as discussed in Chapter 1. As pointed out by Görg *et al.* (2005), in the short run domestic plants that are engaged in international outsourcing may have greater access to internationally traded inputs at lower costs/higher quality than is available domestically; in the long run, such outsourcing activity may also bring about a reallocation of factor shares, and consequently a further impact upon productivity. Therefore the increasing use of internationally traded inputs might be expected to boost productivity in these 'extroverted' plants.

In addition, Grossman and Helpman (2005) have developed a general equilibrium model to theoretically analyse the relationship between trade and outsourcing. Motivated by this work, several empirical studies have emerged to test the implications of the Grossman and Helpman (*op. cit.*) model. Egger and Egger (2006) examine the link between international outsourcing and labour productivity (of low skilled workers) and find that in the short run, the productivity of low skilled workers is negatively correlated with cross-border fragmentation in the EU; whereas in the long run, this linkage turns out to be positive. This turnaround is explained by short-run labour market rigidities and long-run factor mobility respectively. Based on panel data from Irish manufacturing, Görg *et al.* (2005) also provide empirical evidence of positive productivity gains attributed to international outsourcing for Irish firms that export.

2.1.8 Other Factors Determining Exporting

In addition, there is well-documented evidence on how the size of a firm affects its export behaviour, as larger firms are expected to have more (technological) resources available to initiate an international expansion (for instance, Aw and Hwang, 1995; Roberts and Tybout, 1997; Wakelin, 1998; Bleaney and Wakelin, 2002; Cassiman and Martinez-Ros, 2003; Gourley and Seaton, 2004; and more recently, Kneller and Pisu, 2007).

In line with the prediction of 'stock option' theories on export behaviour, exchange rates have generally been found to affect a firm's exporting behaviour. The impact of exchange rate variability on the decision to export is ambiguous a *priori*. Uncertainty about profits from export sales in a foreign currency could increase as a result of a more variable exchange rate, and therefore, more risk-averse firms may be put off from entering new markets. Conversely, firms may judge entry into foreign markets in the same way as a financial or 'stock option' decision that is only exercised in favourable conditions; therefore the variability of the exchange rate could result in more value of the option (Sercu and Vanhulle, 1992). In this sense, exporting becomes more profitable when the exchange rate becomes more variable. Empirically, in the context of the Sterling-Dollar exchange rate, Gourlay and Seaton (2004) demonstrate that the relative level of sterling has a significant impact on both the market-entry and expansion decisions of exporters, although the impact of Sterling volatility varies substantially across industries[17]. For Italian firms, Basile (2001) is able to show that a devaluation in exchange rate reduces the importance of technological competitiveness in its impact on exports, as it allows the non-innovating firms to enter foreign markets.

[17] In the context of UK trade performance (exports in particular), Anderton (1999) shows that the substantial, but temporary appreciation of sterling in the early 1980s caused permanent damage to both the UK's trade performance and industrial base.

2.2 Main Determinants of Innovative Activity in the Literature

The key factors that are frequently documented in the literature to determine R&D spending at the micro level include firm/plant size, absorptive capacity, ownership characteristics (e.g. foreign ownership), technological opportunity and/or appropriability (usually proxied by industry structure and market concentration), R&D spillovers, markets served (especially through exporting), barriers to innovation (e.g. cost of finance), and lastly, government policy instruments (e.g. fiscal instruments, direct subsidies for R&D) (*c.f.* Shefer and Frenkel, 2005).

As in the case of examining exporting orientation, the subsequent empirical study of the determinants of R&D spending deploys a two-stage approach that models which establishments undertake R&D and then how much is spent on R&D per unit of sales, conditional on stage one. Thus accordingly, some of the variables that are discussed below may feature in only one of the stages and/or impact differently between two stages.

2.2.1 Size

Size has been widely recognised to exert a strong influence on innovation undertaken by firms. As pointed out at the outset of Chapter 1 (p.4), academic interest on organisational size probably dates back to Schumpeter (1947) and his assumption that in a mature capitalist society, innovation activity in terms of R&D increases more than proportionally with firm size. Several arguments have appeared in the literature in support of this Schumpeterian hypothesis, along with frequent empirical findings of a positive size effect on R&D activity. For example, Cohen and Klepper (1996) show that R&D rises monotonically with firm sizes across all firm size ranges, with firm size typically explaining significantly more than half of intra-industry variation in R&D activity. Size has been traditionally argued to confer the following major advantages in conducting R&D. Above all, larger firms (*cet. par.*) may be better tuned to exploit economies of scale and scope in the process of undertaking R&D (Schumpeter, 1947; Cohen and Levin, 1989). Secondly, larger size may be associated with higher returns to R&D due to the spreading of fixed costs and risks over output in larger firms (Cohen and Klepper, 1996; Legge, 2000). Another claim is that in a capital market characterised by asymmetric information and market imperfection, larger size may enable the firm to access financial capital with more ease by spreading risks over a portfolio of projects and stabilising internally-generated funds.

Most importantly, the RVB implies that size could be reasonably expected to be related to the absorptive capacity of a firm, benefiting complementary activities between R&D and other functions, such as marketing, manufacturing and learning via internal and external sources. Therefore, from a resource-based viewpoint, larger firms have the advantage of being more able to develop and appropriate the complementarities with other functional activities (Cohen, 1995; Cassiman and Veugelers, 1999; Whittington *et al.*, 1999). Lastly, larger firms are also argued to be better placed to internalise R&D spillovers due to product diversification (Cohen *et al.*, 1987, Acs and Audretsch, 1991 and Almeida *et al.*, 2003, from a learning perspective; also Lichtenberg and Siegel, 1991, Cohen, 1995, Legge, 2000 and Henderson and Cockburn, 1996, for empirical evidence).

Despite the early widespread appeal of the Schumpeterian argument that larger firms are more likely to undertake R&D and/or have higher R&D intensity, early empirical tests exploring this positive scale effect tended to be inconclusive, and the findings rather mixed, casting doubt on a simple positive relationship between organisational size and R&D. Two counter arguments are discussed by Cohen *et al.* (1987). In the first instance, they suggest that the traditional claims on advantages of size often fail to take adequate account of the appropriate unit of analysis. For instance, the argument on capital market imperfection predicts a relationship between innovation and overall firm size, whereas the costs-spreading argument is associated with the plant unit level. More importantly, they further indicate that the arguments in favour of the Schumpeterian hypothesis often unfairly ignore inter-industry differences in the size-R&D relationship, which may result in a spurious statistical relationship between them. Indeed, one would expect the association between size and innovation activity to vary across industries, due to their distinct technological opportunities, market structures, as well as demand characteristics.

In the Cohen *et al.* (*op. cit.*) study, the impact of size on R&D becomes statistically insignificant after controlling for industry effects. Moreover, Acs and Audretsch (1987) find that larger firms conduct more R&D in highly concentrated sectors, whereas smaller firms are more innovative in sectors with low concentration. Holmes *et al.* (1991) indicate that "R&D intensity varies with firm size in some industries but not in others, and where it does vary, there is more evidence that R&D intensity is negatively rather than positively related to firm size." Cohen and Klepper (1996) also find evidence on substantial industrial variation associated with the size and innovation relationship – in those industries where innovations are more saleable and where growth prospects of innovation are greater, the link between *ex ante* size and R&D is weaker.

More recently, another attempt to explore the R&D-size relationship involves a 'threshold' argument (e.g. Cohen and Klepper, 1996). This literature basically implies that until they reach a threshold size level, most firms do not undertake R&D as they cannot generate the *ex ante* profits that will cover the fixed/sunk cost of undertaking this. For example, González and Pazó (2004) show that a firm performs R&D only when its optimal level of R&D expenditure is higher than a threshold level, with determinants of this threshold including a minimum viable expenditure, technological opportunities as well as demand characteristics, all of which may be associated with firm size to some extent. Above this 'threshold' the positive size-R&D intensity relationship breaks down.

Indeed, a negative association between size and firm R&D intensity has been identified amid innovating firms once controlling for industry effects (Cohen *et al.*, 1987; Cohen and Klepper, 1996; Love and Roper, 2002; Almeida *et al.*, 2003). Doubts have been cast on a straightforward and positive relation between size and innovation productivity, thanks to arguments linked to inefficiency due to bureaucracy and loss of managerial control, as well as observed lower average productivity associated with more R&D expenditure prevalent in large firms (Griliches, 1980; Acs and Audretsch, 1991; Graves and Langowitz, 1993; Cohen and Klepper, 1996; Klepper, 1996). Thus, a curvilinear or U-typed relationship between size and R&D performance has also been documented in some of the literature, which may present a holistic perspective and thus better capture the intrinsic complexity in the R&D-size relationship (Pavitt *et al.*, 1987; Almeida *et al.*, 2003; Artz *et al.*, 2003; Tsai, 2005)[18].

In particular, Artz *et al.* (2003) argue that beyond a certain point – presumably in terms of size – R&D spending should bring about substantial synergies that will eventually decrease the investment required for additional products. Moreover, many of the subsequent innovations are likely to be directed to the development of simply add-on products or product extensions, rather than radically new innovations/inventions, which involve a lower premium than the initial investment. Taking this point further, if smaller firms that cross the 'threshold' undertake more by way of product (rather than process) innovation, while larger firms concentrate proportionately more on incremental (process) innovation, assuming that product innovation is much more R&D intensive, then this may account for a negative size-R&D intensity relationship once barriers to undertaking R&D have been overcome.

In a nutshell, the relationship between R&D and organisational size is complicated in nature, which may be better perceived as depending on what other factors (such as industry effect) intervene and whether it is R&D intensity or just the decision to undertake R&D that is being examined. On the whole, size may be expected to exert a positive impact on a firm's decision to undertake R&D; but above a threshold size amongst R&D performers, this relationship may not necessarily be linear, particularly when other factors are taken into account.

2.2.2 Absorptive Capacity

The importance of absorptive capacity in determining the firm's innovation activity is at the heart of issues addressed in this thesis. When setting out the overall theoretical background from an RBV perspective, the crucial role played by absorptive capacity has been discussed in Chapter 1 (pp.11-17).

[18] For instance, Tsai (2005) finds evidence on an approximating U-typed relationship between innovation productivity and firm size, showing both large and small firms have higher competitive advantage vis-à-vis those of moderate size.

2.2.3 Ownership

The impact of (external) ownership on the firm's R&D activity has been extensively researched especially in the empirical literature. Previous analysis using the Science and Technology Policy Research (SPRU) database [19] on significant post-war UK innovations has documented important regional disparities in rates of innovation. Rather, several inter-related factors pertaining to external control are at work during the post-war period, which adversely affect the innovative capability of the peripheral regions. Firstly, using the SPRU database, it is found that over time there has been a movement towards a greater proportion of innovations being developed in independent plants, which suggests that, concurrent with the growth of 'external ownership', the most innovative independent plants (usually smaller and located in peripheral regions) are taken over by larger technologically-advanced enterprises. Secondly, the South East is increasing its share of innovations in externally-owned plants throughout the post-war period, largely at the expense of the peripheral regions, and this strongly suggests that large multi-regional enterprises are concentrating their research activities in the South East where most of them have their headquarters and major on-site R&D facilities, to the detriment of the peripheral regions (e.g. Howells, 1984).

In addition, Harris (Table 2, 1988) records the low level of innovativeness in the peripheral regions of the UK (and especially Northern Ireland) in the 1945-1963 and 1964-1979 periods. Findings also show that traditionally the peripheral regions have produced proportionately more process than product innovation and that over time the concentration of innovations in larger externally-owned plants has resulted in an even greater relative importance being placed on process innovations in these regions. Lastly, the literature has emphasised the importance of knowledge, information and skills in the inventive process (for earlier work, see Freeman, 1982; Gibbs and Edwards, 1985; more recent work on the link between knowledge and innovation will be discussed in a later section

[19] This data source is managed by the Freeman Centre, University of Sussex. For more information, visit http://www.sussex.ac.uk/spru/. See also Pavitt *et al.* (1987) for a discussion of this database including its limitations.

when considering the importance of knowledge spillovers, pp.49-54)[20]; and it is generally recognised that (overall) the South East is the main source of the technological information and skilled workers necessary to introduce innovations in the UK.

Taking R&D activity in Northern Ireland for instance, Harris (1991) shows that plants operating in Northern Ireland that have their headquarters outside the region are some 40 per cent less likely to have an R&D department in the Province; whilst having such an R&D department increases the likelihood of patenting an innovation by some 23 per cent (which is more important than the availability of technical workers and/or firm size on innovativeness). Moreover, Harris and Trainor (1995) suggest that the growing external-ownership, and the resulting branch plant status of many peripheral regions, have lowered the inventive capabilities of such regions. Lastly, most recent evidence on the ownership-innovation relationship is documented by Love *et al.* (2008), who also investigate the extent to which the external ownership moderates the innovation-profitability linkage, using plant-level data from the manufacturing industries in Ireland and Northern Ireland covering the 1991-2002 period. Their findings confirm the disparities in the innovation patterns between indigenously-owned and externally-owned plants as well as rather distinct sets of determinants of profitability between these two groups.

2.2.4 Technological Opportunity

How the business environment shapes innovative behaviour has long been the focus of extensive theoretical and empirical work. Studies undertaken in this area consider how a firm's innovative efforts are determined by structural factors in terms of technological opportunities (e.g. Cohen *et al.*, 1987; Klevorick *et al.*, 1995; and Cincera, 1997), appropriability (e.g. Levin *et al.*, 1987) and the degree of market diversification/concentration (e.g. Scherer, 1965; Levin *et al.*, 1985).

[20] For example, Nesta and Saviotti (2005) recently find that two properties of the knowledge base, viz. its scope and its coherence, contribute positively and significantly to the firm's innovative performance in the US pharmaceutical industry.

It is generally acknowledged that business decision to innovate varies significantly across industries because of distinct technology dimensions there such as technological opportunities, market dynamics, appropriability regimes and demand pull factors. Most importantly, technological opportunity is the concept widely used in the literature to capture various technological advances for each industry occurring at different speed and with varying degrees of difficulty (Klevorick *et al.*, 1995). Thus Jaffe (1986) defines technology opportunity as exogenous variations in the cost and difficulty of innovation in different technological areas. The type and nature of the technological results acquired by a firm are directly determined by the technological opportunity the firm faces, which will eventually exert a crucial impact upon its resource base and the probability of investment in innovative activity. It follows that firms operating in technological and scientific environments with a higher level of technological opportunity tend to be more motivated for undertaking R&D.

The role of technological opportunity in determining business R&D effort is well established in a number of empirical studies. In particular, Scherer (1965) was the first to introduce industry dummy variables to capture inter-industry differences in terms of technological opportunity in explaining innovation rates, and since then this approach has become a widely adopted empirical practice (for want of a better way to capture technological opportunity). Utilising this approach, Levin and Reiss (1984), Angelmar (1985), Jaffe (1986) and Geroski (1990) argue that the costs of developing and introducing new innovations should be lower in industries with greater technological opportunity, providing a supply-side push to innovation. Empirically, Cohen *et al.* (1987) find that sector dummy variables explain half the variance in R&D intensity in their data; Geroski (1990) find at least 60% of the variation in R&D could be explained by industry effects. Koeller (2005) confirms the role of technological opportunity in determining the nexus between innovation output of different-sized firms and concentration across industries. Other empirical studies have also documented a positive linkage between the level of technological opportunity facing a firm and its R&D efforts, e.g. Klevorick *et al.* (1995), Cincera (1997), Veugelers (1997) and Shefer and Frenkel (2005).

2.2.5 Industrial Effects

Going hand in hand with the impact of technological opportunity is the existence of industry effects, in terms of variation in technological characteristics amongst different sectors. This has provided a rationale for grouping firms into high-tech and low-tech industries (*c.f.* Acs and Audretsch, 1993; Frenkel *et al.*, 2001). For instance, electronics and precision instruments are often referred to as high-tech sectors; whereas food, drink, plastics and metal products are often regarded as traditional/low-tech sectors (Shefer and Frenkel, 2005, for example, find evidence of significant difference in R&D between firms affiliated with high-tech industries and the traditional ones). Nevertheless, this OECD classification can be rather misleading if one simply equates high-tech to better development and performance (see von Tunzelmann and Acha, 2005). As argued by Crespi *et al.* (2003), this measure of technological performance is principally defined by firms' product range. However, even firms in low-tech industries can be heavily involved in innovative activity during the production process, say by assimilating technology generated from those at the technological frontier. For instance, modern biotechnology, computerisation, advanced instrumentation may be utilised in the food-processing industry, although food as the final product is designated a low-tech product. In this sense, low-tech industries are the users/carriers of technological knowledge; and from a RBV perspective, the complementariy between the two faces of R&D indicates that R&D efforts made for the purpose of imitating/assimilating technological knowledge acquired elsewhere may be as significant as those for generating new technologies (*c.f.* the discussion on complementarity between internal and external R&D on p.14).

In addition to variations across distinct industries, market power[21] has been widely perceived to exert considerable influence on a firm's innovative decision (*c.f.* the related discussion on market power in Chapter 1, pp.8). The relationship between industry concentration and R&D intensity is sometimes analysed in the context of different technological opportunities across sectors. For instance, Globerman (1973) argue that a high degree of industry concentration is unlikely to promote innovation in technologically progressive industries, particularly in large firms. In a similar fashion, Angelmar (1985) finds

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[21] This is usually measured using a concentration index, such as the Herfindahl index.

market concentration to be negatively associated with R&D investment in technologically progressive industries, since it effectively reduces the need to introduce new technology/products. Scherer and Ross (1990) suggest that multi-seller rivalry is most conducive to undertaking R&D in the presence of diverse technological opportunities. Most recently, Koeller (2005) has identified technological opportunity as a crucial factor influencing the nexus between innovation in different-sized firms and industry concentration. Nevertheless, the empirical evidence is still not conclusive; for instance, Scherer (1965) suggests an inverted-U relationship in the sense that not too little and not too much rivalry in the industry seems most conducive to research activity.

2.2.6 Knowledge/R&D Spillovers

It is acknowledged that, as a public good, knowledge spillovers (or R&D spillovers as a specific example) may allow recipient firms to achieve certain technological standards without too much effort. This resulting free-rider problem may provide a disincentive to invest in innovation activity, as innovating firms will incur the costs but may not make exclusive use of the benefits. In this sense, Spence (1984) indicates that firms which operate in environments with considerable spillovers have only a very weak incentive to invest in innovation. Moreover, for the recipients of R&D spillovers, the increasing use of public technological know-know may substitute for their internal R&D activity and therefore reduce the effort they put into such activities (Henderson and Cockburn, 1996). In all, the spillover effects of R&D may result in certain market failures because of the externality and even public good elements that result in individual firms not valuing their own R&D efforts sufficiently, and thus under-investing in the activity.

However, given the earlier discussion on the role of knowledge generation and in particular the importance of absorptive capacity (*c.f.* pp.11-17, Chapter 1), it seems unlikely that the pure externality (or public good) element of R&D spillovers is large (i.e. that firms can freely and easily assimilate such external knowledge); rather as already discussed, the impact of spillovers on a firm's innovative efforts is crucially dependent on its absorptive capacity. Cohen and Levinthal (1989, 1990), drawing on theoretical and empirical evidence, suggest that a firm needs to make efforts and invest in its absorptive capacity so as to appropriate knowledge spillovers from other firms. To put it another way, the desire to assimilate the external knowledge spillovers creates incentives to invest in R&D so as to effectively absorb this external know-how. Recent studies have investigated the importance of absorptive capacity in exploiting external R&D spillovers; for instance, Veugelers (1997), Blomström and Kokko (1998), Leahy and Neary (2008), and also in a context of international knowledge spillovers, Griffith *et al.* (2004) and Girma (2005). In general, positive spillover effects on absorbers' innovative efforts have been widely identified.

2.2.7 External Localisation

Alongside the spillovers of knowledge/R&D, another important factor determining innovation is the localisation of such spillovers that facilitates knowledge/resource creation, i.e. the spatial factors. While such spillovers may be technologically restricted to a particular industry to which a firm belongs or to other industries that share a common technology base, it is equally likely that they may also be geographically restricted in that the firm need to be close enough to the source of spillovers in order to acquire and appropriate such tacit knowledge (which is likely to be transmitted only through mechanisms that require spatial proximity). Morgan (2004) maintains that tacit knowledge is person-embodied and context-dependent and therefore is, by its location, 'sticky'. Others stress that the exchange or transmission of tacit knowledge relies on reciprocity and trust, and that the operationality of these relational assets requires physical proximity (e.g. Nonaka and Takeuchi, 1995; Malmberg, 1997). Moreover, the importance of transmission costs has also been emphasised in the literature in that the costly nature of knowledge transmission necessitates proximity; for instance, von Hippel (1994) points out that the information required by a firm and the problem-solving capability it needs to assimilate such information must be brought together at a single locus. Thus, Audretsch and Feldman (1996) find evidence on the spatial concentration of innovation activity in the US and, more importantly, that the impact of knowledge spillovers is more significant in determining the clustering of innovation activity than the mere geographic concentration of production.

In addition, high-tech firms located in central areas, for instance, are found to be more willing to invest in innovation activity than those in peripheral areas (*c.f.* Davelaar and Nijkamp, 1989; Audretsch and Feldman, 1996; Audretsch, 1998). Shefer and Frenkel (2005), in particular, point out that R&D tends to be concentrated in large urban areas and a firm's location affects its rate of R&D expenditure.

More generally, the notion of geographical agglomeration or industrial clustering of similar firms has been broadly perceived as a major source of innovation and knowledge creation (OECD, 1999), which involves a network of research actors including businesses, industries, government laboratories, academic sectors, research institutes, etc. The rationale for industrial agglomeration is self-evident from both supply and demand viewpoints. First, on the supply side, the benefits of clustering are crucially underpinned by the notion of external networking amongst firms in similar/inter-related industries. Building up these strategic alliances with inter/intra-industrial firms helps create a pooled market for employees with analogical skills and competences, therefore significantly enhancing the firm's capability of appropriating external knowledge and diversifying risks associated with unemployment and aggregate business cycles (Krugman, 1991). For instance, Keizer *et al.* (2002) suggest that collaboration with suppliers can overcome size constraints and spread costs and risks of new technology.

The arguments from the demand side are two-fold. On the one side, industrial agglomeration facilitates a firm's exploitation of local demand, particularly the demand generated in related industries; on the other side, firms can also cluster to provide customers with easier access, to minimise search and transaction costs, and therefore to achieve enhanced profitability. For example, Hipple (1988) shows that by locating near to key users and establishing customer services, firms can take better advantage of flows of information from customers that constitute a vital source of ideas for innovation. There is a growing body of both theoretical and empirical literature capturing the impact of clustering on a firm's R&D efforts/performance (Krugman, 1991; Swann and Prevezer, 1996; Baptista and Swann, 1998; Diez, 2000; Keizer *et al.*, 2002; and Sher and Yang, 2005). Krugman (1991), for instance, has investigated the existence of positive knowledge externalities central to the notion of clustering, and developed a theory of regional specialisation of industrial activities based on the advantage of specialised labour, intermediate goods and these externalities. Diez (2000) argues that the complexity of the innovation process involves interactions among the basic research actors and thus spillover effects, resulting in business innovation occurring spatially close to research institutes.

Nevertheless, the relationship between industrial clustering and innovation may be far more complicated (non-linear) than it appears to be, due to increasing price competition and congestion costs, as a cluster grows. Baptista and Swann (1998) predict the limits to the positive feedback process where clusters are self-reinforced, and they further argue these limits are related to congestion and competition effects arising from input and output markets. Based on evidence from Taiwan's semiconductor industry, Sher and Yang (2005) find a moderating impact of (R&D) clustering on the relationship between innovative activity and a firm's performance – an appropriate level of (R&D) clustering positively influences this relationship, whereas congested clustering is likely to have an adverse effect on this relation, and therefore deters R&D efforts. It follows that it is reasonable to expect industrial/spatial clustering to exert a positive impact on a firm's innovating behaviour when clustering occurs at a low or moderate level; however, this relationship no longer remains linear as clusters further develop.

Thus, the geography of knowledge spillovers has received increasing attention in more recent literature, and positive regional spillover effects have been well documented (Feldman, 1999; Harhoff, 1999; Cantwell and Iammarino, 2000; Roper, 2000; Co, 2004; Fritsch and Franke, 2004, to name just a few). Nevertheless, a key issue in any empirical analysis involving knowledge spillovers is the measurement of the pool of external knowledge, given that a firm can appropriate different amounts of knowledge according to its geographical and technological distance from members of this pool. This concept of distance is usually implemented empirically by the amount of R&D conducted elsewhere weighted by some measure of proximity in the technological and/or geographical space (*c.f.* Jaffe, 1986, 1989; Bernstein and Nadiri, 1989; Goto and Suzuki, 1989; Acs *et al.*, 1992; Jaffe and Trajtenberg, 1992; Park, 1995; Audretsch and Feldman, 1996; Sena, 2004). For example, Bernstein and Nadiri (1989) use the unweighted sum of R&D spending by other firms in the same industry, on the assumption that this captures intra-industry knowledge spillovers between firms sharing the same technology. A weakness is the assumption that a firm benefits from R&D of all other firms in the same industry but not from the R&D conducted by firms in other industries where the technological base may be similar. Thus, the sum of R&D spending in other industries may also be separately included to capture inter-industry spillovers, but both these measures and the intra-industry measure run the risk that they are picking up spurious effects due to common industry trends and shocks.

First introduced by Jaffe (1986), with respect to technological space, a more sophisticated approach to measuring technical and geographic proximity is to use relevant data to position a firm in its technological and geographic space. For example, each firm can be linked to a vector describing the distribution of its patents (or its R&D spending) across technology classes (or product fields). Thus, the firm is linked specifically to those industries and localities from which it potentially obtains (or supplies) information. Admittedly, this may still not be picking up knowledge spillovers but rather what Griliches (1996) terms "spatially correlated technological opportunities" since technological or geographic proximity is likely to be correlated with exogenous technological or spatial opportunity conditions; that is, if new opportunities exogenously arise in a technological or geographical area, firms active in that area will all increase their R&D spending, and this would erroneously show up as a spillover effect.

In any event, technological (tacit) knowledge linked to geographic proximity may spillover through informal contacts (industry conferences, talks, seminars) between firms that share the same location, rather than more formally through patented information and/or R&D links. Thus, even if information is available to sum the weighted values of industry and/or geographical R&D, this may not capture the full extent of potential knowledge spillovers. Industry and regional (dummy) variables included in the model may also be picking up some of the benefits from geographical agglomeration or industrial clustering (and more specific variables capturing such agglomeration and clustering effects can of course, also be used).

Despite the obvious difficulties of measuring knowledge spillovers associated with technological and geographic proximity, various studies have found evidence that such spillovers do exist. For example, Keller (2004) finds evidence of spillovers from R&D on a geographical basis, with such benefits for major industrialised countries declining with distance. In a similar vein, Fritsch and Franke (2004) find positive spillover effects from public and private R&D conducted outside the firm on its innovation performance. Others have also found evidence of some kind of positive intra-regional R&D spillovers (*c.f.* Kelley and Helper, 1999; Sternberg, 1999; Lissoni, 2001; Co, 2004). Some studies have presented evidence of positive inter-regional R&D spillovers, although these tend to decay with distance (*c.f.* Caniels, 2000; Verspagen and Schoenmakers, 2004; Cantwell and Piscitello, 2005). More significantly, Peri (2005) uses patent data for a panel of 113 European and North American regions over 22 years, finding that the externally accessible stock of R&D has a positive impact on firm innovation but that only about 20 per cent of average knowledge is learned outside the region of origin and only 10 per cent outside the country of origin. In contrast, Lehto (2007) uses R&D data for Finnish firms and shows that only when other firms' R&D is located in the same sub-region is there any positive spillover effect. On this basis, spillovers are important but they appear to be rather localised.

2.2.8 Internationalisation

The objective of serving foreign markets is likely to be another important driver of undertaking innovative activity (see next section, pp. 59-69, for an evaluation of the export-innovation linkage). As reviewed in Chapter 1 (pp.28-32), the more recent economic models of internationalisation (e.g. Bernard *et al.*, 2003, 2007; Melitz, 2003; Helpman *et al.*, 2004) focus on the importance of sunk costs and heterogeneity across firms (particularly differences in productivity). To overcome entry costs, firms need an adequate knowledge-base and complementary assets/resources (especially R&D and human capital assets that lead to greater absorptive capacity); and of course productivity differences rely on firms having differing knowledge and resource-bases associated with differences in rates of innovation and other aspects of TFP. There is empirical evidence of a positive link between a firm's exporting activities and its R&D expenditures and/or innovation activities (e.g. Greenhalgh, 1990; Braga and

Willmore, 1991; Buxton *et al.*, 1991; Ito and Pucik, 1993; Kumar and Saqib, 1996; Wakelin, 1997; Canto and González, 1999; and Sterlacchini, 1999).

2.2.9 Market Failures and Barriers to Innovation

There are specific barriers to innovation that are likely to impact on whether R&D is undertaken at all (and, if so, how much is invested in such activity). These barriers are often discussed within the context of market failure arguments for government intervention whereby it is argued that because R&D involves a significant level of risk and uncertainty coupled with large (irreversible) sunk costs, there is a tendency for the private sector to invest at a lower level than is warranted by the higher social returns associated with R&D. Note, there are two aspects to market failure that need to be considered: firstly, that because of spillovers firms cannot appropriate the full returns from any investment and therefore will under-invest (i.e. social returns are higher than private returns); and secondly, there are market imperfections particularly in information and the ability of firms to raise finance for R&D (with such imperfections most likely to impact on smaller firms).

Appropriability failure occurs when investments in innovative activities do not yield the necessary property rights which can be reserved for the exclusive use of the investor. Information once released becomes public knowledge and is easily diffused and thus property rights are often difficult to enforce. In this instance, the problem is partly one of coordination: the seller of innovation may have to disclose (or cannot prevent disclosure of) details of such innovation outcomes[22]. The purchaser and vendor therefore cannot coordinate effectively and at the same time allow the innovator to extract the full private rent from the innovation. This, therefore, leads to a disincentive to innovate, and cannot usually be corrected through institutions (such as patenting and licensing bodies) that grant perfect property rights that are enforceable. It is also important to note that there are benefits as well, given the inability to fully appropriate information leading to spillovers to other firms and perhaps the wider economy. In addition, as Geroski (1995) shows, even if spillovers occur this does not

[22] This is the Arrow paradox (1962). If a full description of a technology must be communicated prior to any transaction this obviates the need to buy and so the seller has good reasons not to disclose their full knowledge.

necessarily undermine the incentives to innovate since firms must typically invest in R&D themselves in order to benefit from external knowledge pools, so in this situation spillovers may actually stimulate R&D through the need for a firm to invest in absorptive capacity.

Financial barriers are usually deemed to be a market failure when (particularly) SMEs find it difficult to convince potential lenders or equity providers to support them because they have insufficient collateral and/or a track record to reduce the risk associated with the innovation activity. To the extent that the problem is due to financial institutions and the owners of firms taking a short-termist approach (leading in part to problems of corporate governance, adverse selection, moral hazard and principal-agent issues), this barrier may be deemed an institutional failure. Thus, there would appear to be good grounds for government intervention, perhaps in the form of subsidies or loans, or in attempting to provide a 'missing market' such as the encouragement (through tax concessions) of suppliers of venture capital. Missing markets have just been used as an example of market failure. The more usual example occurs with respect to future (missing) markets where the necessary suppliers/customers are not easily identified due to technological advance.

Barriers to entry and exit are mostly the consequence of scale/scope economies, translating into (absolute) cost advantages associated with size. As a result of technological advances, these barriers can be natural and incremental; whereas industries where firms have substantial market power often seek to strategically use sunk cost investments (say in R&D, or other capacity-building practices) to create artificial barriers to exit that then lead to barriers to entry for others. That is, the incumbent firms are able to set prices (in the sense of Bertrand competition) or output (in a Cournot setting) at levels that allow them to just cover their costs but make it difficult for new entrants to break even without having to first invest substantially in, for example R&D, and thereby incurring sunk costs that can hardly be covered in the short run. This discourages new firms (especially SMEs) from entering, given the high entry barriers as well as the fact that once into the market it is not economical for them to leave.

In a broader context, there are various types of failures associated with the networks, systems and government in general, which could adversely impact upon business innovation activity. Above all, network failures arise when firms are not well connected to other firms with an overlapping technology base or when the network goes in the wrong direction and takes firms with it. Carlsson and Jacobsson (1997) have emphasised the importance of good networks in that i) they may improve the resource base of the firm (shaping the internal capabilities of firms), thus making it more receptive; and that ii) "…the character of the networks to which the firm belongs has a bearing on the type of information and knowledge to which the firm has access… (so) innovation and diffusion turns… into a collective activity, in addition to being an individual one.. (and thus) networks are central to the innovation process" (p. 301).

On the other side, network failures may also arise for technological know-how (loosely defined) is partly tacit and thus cannot be diffused easily. This is argued to be especially important in the diffusion process where transfer depends on inter-personal contacts. Here networks can be important for the transfer of such tacit knowledge and also for the solution to problems associated with firms experiencing bounded rationality and consequently bounded vision. However, as argued by Teece and Pisano (1998), even where networks assist in providing information, replication and imitation are not usually easy especially if productive knowledge is embodied in the dynamic capabilities of firms. They further point out that if the tacit component in the diffused technology is high and firms fail to employ key individuals with knowledge on crucial organisational processes, replication and imitation may be impossible.

From both the perspective of firms and markets, government failure arises when the government has a comparative advantage in supplying a good or service (especially knowledge/information), but fails to do so. A classic example is the provision of public goods, where because of the free-rider problem the private sector would produce too low a level of demand and thus consumption and production, to the detriment of the society. Education and institutions involved in basic scientific research are examples of outputs with public-good elements.

Finally, there is also the issue of systemic failure at the level of the entire technological system. The evolutionary model of technological change emphasises that what we know about the sources, determinants and outcomes of the process points to the complexity and systemic nature of innovation. As

Dodgson and Bessant (1996) put, “thus while individual firm competence is the central basis of innovative performance, firms operate within ‘systems of innovation’ which intermesh their activities with those of other organizations” (p.20). Various authors (e.g. Patel and Pavitt, 1997) stress that firms are located within specific regional (or national) technological systems which contain specific and unique competencies, networks and institutions that define the context in which the firm operates. Systems are highly complex, involving the financial, educational, science and technology institutions in the region or nation, all of which impact directly on the operating environment of the firm, but these systems also involve more difficult to measure elements such as culture and the legal and statutory framework which may help or hinder development.

2.2.10 The Role of Government

Government intervention is often justified on the grounds that there has been a market failure due to the costs of acquiring information. This is argued to be particularly important for SMEs. Within the traditional Arrow-Debreu static model of general equilibrium with perfect competition, there is a presumption that communication costs that inhibit perfect and instantaneous distribution of information result in a market failure. Nevertheless, this market-failure approach has been at the heart of numerous controversies primarily centring on the highly unrealistic/untenable assumptions on the economy. Taking one step further, from an evolutionary viewpoint, it can also be argued that information costs leading to asymmetric outcomes are in fact one of the features of the market, and they are in part necessary as a selection device (for promoting the fittest firms) and in providing incentives for learning and discovery, which is crucial to the process of variety creation. As Metcalfe and Georgiou (1997) point out, “a profit opportunity known to everybody is a profit opportunity for nobody”.

Nevertheless, this does not mean that there is no rationale for government intervention, assuming that it sees a direct increase in economic benefits from more firms gaining information and thus acting on that information (e.g. by adopting certain technologies, increasing their overall capabilities, etc.). Casson

(1999) argues that in this situation the government has a comparative advantage in information, and it is on this basis (not market failure) that it can justify intervention. Based on the rationale of government combating market failures, there are two main ways in which governments can directly influence the level of R&D spending within firms: by directly subsidising such expenditures through grants and/or loans or by offering fiscal incentives.

In the context of the government's innovation policy, the literature that considers the effectiveness of government grants to increase private sector R&D reaches very mixed conclusions. Partly this reflects a concern that direct subsidisation of R&D may have a high deadweight component (as firms free-ride on such subsidies); it also reflects the fact that many government schemes are aimed at longer-term outcomes (including pre-commercialisation R&D spending), rather than projects that generate near term profits (which are more receptive to fiscal incentives, as discussed below). Thus Busom (2000) for Spain; Czarnitzki and Frier (2002) for Germany and Lach (2002) for Israel, all report negative (or insignificant) links between R&D subsidies and private R&D expenditures at the firm level. Surveys by David *et al.* (2000) and Klette *et al.* (2000) also report a wide array of evaluations results.

In contrast, fiscal incentives allow government to finance a portion of the R&D undertaken by firms that qualify automatically through the tax system, and it is argued that they are more likely to favour projects that generate near term profits. The use of fiscal incentives, such as tax allowances or deferrals or (the most favoured) tax credits, has been increasingly used in a number of countries (OECD, 2002).

2.3 The Export-Innovation Nexus

2.3.1 Theoretical Framework

The linkage between innovation and exports has been characterised by increasing interdependence in the process of globalisation, and is often regarded to be of paramount importance to an economy: innovation is commonly taken as a proxy for productivity and growth, and exporting for competitiveness of an industry/country. At the macroeconomic level, this relationship between trade and innovation often relates to several distinct paradigms, such as the Schumpetarian idea of creative destruction (Schumpeter, 1947) as well as the Prebisch-Singer model of the trade patterns between developed and less developed countries (Prebisch, 1950; Singer, 1950).

The macroeconomic literature offers at least two mainstream theoretical models to account for this relationship: neo-endowment models which concentrate on specialisation on the basis of factor endowments, such as materials, skilled/unskilled labour, capital and technology (Davis, 1995); and also neo-technology models which predict innovative industries will be net exporters instead of importers (Greenhalgh, 1990; Greenhalgh and Taylor, 1994). The latter type of models provides an extension to the conventional technology-based models based on for example, the product life cycle theory (Vernon, 1966) and technology-gap theory of trade (Posner, 1961).

In an important pioneering study to address the linkage between trade and innovation (as well as the direction of causality), Krugman (1979) points out that export and import activities of nations are positively related to innovation and technology transfer brought about by trade; further, he argues that the causal chain runs from innovation to international trade and not the other way around. Under the scenario of trade between developed countries (DCs) and less developed countries (LDCs), this model predicts an improvement of relative terms of trade to all parties: innovation improves the terms of trade of DCs whereas the trade-induced technology transfer confers higher innovation content to goods produced in LDCs. Moreover, this model also makes it a necessity for DCs to continually invest in innovation so as to retain their real incomes and growth, as the constant transfer of production from DCs to LDCs will inevitably lead to industrial decline in the former.

More recently, Grossman and Helpman (1995) demonstrate that, in a framework of monopolistic competition, a country could push its export demand curve outwards by increasing the quality of goods it produces; meanwhile, it could shift its import demand curve inwards by increasing the quality of goods produced for the domestic market. These demand-shift factors can possibly be proxied by factors that represent improvements in product quality, i.e. technological innovation.

From the perspective of firms, several earlier theoretical studies maintain that innovating firms have incentives to expand into other markets so as to earn higher returns from their investment, as the appropriability regime is improved when the product market widens (e.g. Teece, 1986). As the domestic market is rather limited (or it is too time-consuming to recover such investment), firms could face an increasingly strong need to expand their product market by different modes of internationalisation. In this process of international expansion, innovation is of great significance for the development of firms' competitive advantage as well as growth potential. For one thing, this competitive advantage conferred by innovation will give firms an incentive to enter global markets and subsequently enhance their performance and international competitiveness in the new markets; in addition, the more competitive international environment that firms are exposed to may provide a source of new ideas spurring more and better innovation by them. In comparison with the well-established trade-innovation theoretical framework in the macroeconomics literature, most evidence at the firm level is empirics-led, and therefore usually lacking a solid theoretical foundation.

The resource-based approach has been explicitly employed in two recent studies (viz. Dhanaraj and Beamish, 2003; and Lopez Rodriguez and Garcia Rodriguez, 2005), offering new insights into this export-innovation relationship, in light of the development of firm's technological capacity[23]. The role of technological resources in firms' internationalisation process can be illustrated by Lopez Rodriguez and Garcia Rodriguez's conceptual model reviewed earlier (see Figure 1-2, p.18), which emphasises the cost/product differentiation advantages conferred by technological resources. These tacit resources, being highly knowledge-intensive, can generate a double competitive advantage for the firm.

These technological resources can, as they argue, lead to the development of new and more efficient productive processes, and therefore confer competitive advantages in costs. On the other hand, they are also associated with

[23] See Chapter 1 for a thorough discussion of this RBV approach.

competitive advantages based on product differentiation (via product innovation), and therefore should enable the firm to tailor products according to customer needs, or enhance the quality of products. They further argue that the current environment – characterised by globalisation coupled with market segmentation and increasing demand for customised products – is pushing the balance in favour of competition via differentiation. Consequently, firms with better technological capacities will enjoy superior competitiveness in both domestic and foreign markets.

2.3.2 Empirical Evidence

Ample evidence has been provided at the macroeconomic level, regarding the linkage between a country's export performance and its creativity/innovation. A uniformly positive correlation has led to a consensus that a nation's exports are positively associated with its knowledge accumulation/innovative activities (Fagerberg, 1988; Greenhalgh, 1990; Verspagen and Wakelin, 1997; Narula and Wakelin, 1998; Leon-Ledesma, 2005; DiPietro and Anoruo, 2006, etc)[24]. For instance, in a most recent study, DiPietro and Anoruo (2006) decompose the notion of 'creativity' into four components, viz. innovation; state of technology; the amount of technology transfer from abroad; and the extent of business start-ups; and find all of these factors to be positively correlated with the value of a country's exports.

In contrast, empirical studies at the firm level provide a rather different and unique perspective to disentangle this export-innovation relationship, taking into account the heterogeneity of firm characteristics amongst exporting and non-exporting firms. As discussed at the outset of this chapter, a firm's export orientation has been extensively investigated in the literature, and various empirical studies have emphasised the role of technology and innovation as one

[24] It is worth mentioning that despite this positive relationship in general, disparity across countries has also been found, particularly when trade takes place between developed and developing (or relatively less developed) countries. For instance, using patents as a proxy for innovation, Narula and Wakelin (1998) find that the patent variable has a significantly positive impact on the export performance of industrialised countries, but a negative one on that of developing countries. They further attribute this discrepancy to the distinct roles that technological capabilities play across countries: these resources only translate into better export performance in the case of industrialised countries.

of the major factors contributing to facilitating entry into global markets and thereafter maintaining competitiveness and boosting export performance. For instance, studies covering UK firms include: Wakelin (1998), Anderton (1999), Bishop and Wiseman (1999), Bleaney and Wakelin (2002), Gourlay and Seaton (2004) and Hanley (2004); for Canadian manufacturing firms, Bagchi-Sen (2001), Lefebvre and Lefebvre (2001) and Baldwin and Gu (2004); for Italian manufacturing firms, Sterlacchini (1999) and Basile (2001); for Spanish manufacturing, Cassiman and Martinez-Ros (2003) and Lopez Rodriguez and Garcia Rodriguez (2005); for German services, Blind and Jungmittag (2004); in comparative studies, Roper and Love (2002), for both UK and German manufacturing plants and Dhanaraj and Beamish (2003) for US and Canadian firms; in the context of the rest of the world, Hirsch and Bijaoui (1985) for Israel; Alvarez (2001) for Chilean manufacturing firms; Guan and Ma (2003) for China and lastly, Ozcelik and Taymaz (2004) for Turkish Manufacturing firms.

The work by Hirsch and Bijaoui (1985) is one of the first studies to examine the relationship between R&D expenditures and export behaviour. They develop a theoretical framework whereby innovation confers monopoly power for innovating firms. This power allows them to discriminate between domestic and international markets; whereas firms not active in innovation-related activities are assumed to be price takers, equipped with fewer incentives/resources to expand into international markets. Therefore, innovative firms are predicted to be more export oriented. Their findings not only confirm the theoretical underpinnings of their model but also suggest that lagged R&D expenditure is significant in explaining the rate of change of exports in a cross section.

In line with these findings, Brouwer and Kleinknecht (1993) later suggest that international cooperative R&D agreements and the purchase of advanced equipment for automatisation positively influence a firm’s export behaviour, although they stress that it is product (rather than process) innovation that make a difference. Similarly, Anderton (1999) analyses how R&D and patenting activity affect trade volumes and prices, finding that both technology indicators could be regarded as proxies for the quality/variety of goods produced. Bagchi-Sen (2001) studies Canadian manufacturing SMEs in the Niagara region, and finds that high levels of product innovation is significantly, positively associated with R&D intensity, growth in R&D expenditure and export intensity. Lefebvre and

Lefebvre (2001) consider more than 3000 Canadian SMEs to separate out the different effects of a number of technology-related variables as drivers of export performance, and conclude that overall these technological variables boost a firm's performance in export markets.

Roper and Love (2002) find evidence of a positive impact of product innovation upon both the probability of exporting and the intensity of exporting amongst UK manufacturing plants, as innovating plants gain more technological spillovers. Nevertheless, comparing UK and German plants, they also imply that this export-innovation linkage could be country specific, particularly in terms of the relationship between innovation activity and the two stages of exporting, along with the plants' capacities for absorbing innovation spillovers. Cassiman and Martinez-Ros (2003) not only confirm the positive effect of innovation activities on a firm's export decision in Spanish manufacturing firms, but also make the distinction between product and process innovations: the former are found to be a more important determinant of export growth whereas the latter are more closely related to export propensity. Finally, in a recent study based on UK CIS data, Hanley (2004) find that, when considering patterns of innovation on export intensity, if firms have derived a part of their sales from products that on the margin has been revamped, tailored or changed in some way, then they usually manifest significantly higher export intensity than those that have not altered their products by any means. They are also able to show that this result is robust across different industries at the two-digit SIC level.

Contrary to the uniformly positive export-innovation linkage revealed in the macro economics literature, some empirical studies at the micro level present contrary findings. For instance, Lefebvre *et al.* (1998) and Sterlacchini (2001) find insignificant association between R&D investment and export intensity. Moreover, based on Japanese manufacturing firms, Ito and Pucik (1993) find R&D intensity to be a significant determinant of a firm's export performance only when size is left out from the regression.

2.3.3 The Causality Issue

Given that most of the empirical evidence confirms that there exists a correlation between the innovation activities and export orientation at the firm level, the next issue to address is the causal direction of this relationship – the issue as to whether being innovative leads a firm into international markets, or whether exporting enhances the firm's technological capacity/innovativeness, or whether such causality runs in both directions. The early consensus in the literature is that causality runs from undertaking innovation activities to internationalisation. This can be easily understood from the perspective of product differentiation/innovation-led exports, which is in line with the predictions of both the more conventional product-cycle models of Vernon (1966) (see also Krugman, 1979 and Dollar, 1986), as well as the recently developed neo-technology models (Greenhalgh, 1990 and Greenhalgh and Taylor, 1994). The intuition behind this causal chain is straightforward: product differentiation/innovation translates into a competitive advantage that allows the firm to compete in international markets.

Overseas markets are usually characterised by an increasing level of competition relative to domestic markets; thus as Cassiman and Veugelers (2002) point out, the marginal value of R&D should be higher for exports than for local sales. Therefore, it is reasonable to expect that higher level of endowments of R&D (or other innovation-related activities in general), which are usually conducive to product differentiation[25], will serve to boost export performance. There is well-documented evidence on how R&D inputs/innovation-related variables are expected to directly raise export intensity (Lefebvre *et al.*, 1998; Bleaney and Wakelin, 2002; Barrios *et al.*, 2003; Cassiman and Martinez-Ros, 2003), or alternatively, to indirectly affect firm-level export behaviour through the intensive use of skilled/technical staff (Starlacchini, 2001).

In earlier work, Hirsch and Bijaoui (1985) illustrate that the propensity to export of firms engaged in R&D is higher than that of the entire branch they belong to. In an attempt to discriminate between innovators and non-innovators, Wakelin (1998) find that these two groups behave differently both in terms of the likelihood of exporting but also in terms of the level of exports, and she concludes that the capacity to innovate fundamentally affects a firm's export performance. After finding a positive impact of innovation on a firm's export behaviour, in an effort to further differentiate the impact amid different types

[25] Note here product innovation and product differentiation are used interchangeably.

of innovation activities, Nassimbeni (2001) shows that export propensity of 'small' Italian firms is affected more by their ability to create new products and develop inter-organisational relations, whilst technological profiles seembmuch less important[26]. In a study of UK firms, Bleaney and Wakelin (2002) find that in the case of innovators, their capacity to innovate is a crucial to their competitive performance, and they conclude that product differentiation is a prerequisite for these firms' entry into export markets. Comparing UK manufacturing firms with their German counterparts, Roper and Love (2002) are able to demonstrate that, despite disparities in various aspects between these two countries, innovativeness is conducive to competitiveness in overseas markets. Lastly, Lachenmaier and Woessmann (2006) have also uncovered analogous evidence for German manufacturing sector: innovation leads to an approximately 10% increase in the share of exports in a firm's total turnover.

Counterarguments on causality going from exporting to innovativeness also exist: primarily, being exposed to a richer source of knowledge/technology often unavailable in the home market, exporting firms could well take advantage of these diverse knowledge inputs and enhance their competency base, and hence in this sense, such learning from global markets can foster increased innovation within firms. The existence of this 'learning-by-exporting' effect is in accordance with the theoretical predictions of global economy models of endogenous innovation and growth, such as in Romer (1990), Grossman and Helpman (1991), Young (1991) and Aghion and Howitt (1998), and it is also consistent with the notion of absorptive capacity and the RBV discussed in Chapter 1.

The causality running from exports to innovation is often not directly measured but considered through the link between innovation and productivity growth. The process of going international is perceived as a sequence of stages in the firm's growth trajectory, which involves substantial learning (and innovating) through both internal and external channels, so as to enhance its competence base and improve its performance. A well-established strand of literature has emphasised the importance of exporting as a learning/knowledge accumulation

[26] In another study of Italian firms, Basile (2001) finds evidence not merely on the higher export intensity of innovating firms vis-à-vis non-innovative ones, but also on the negative impact that exchange rate devaluation has on the conduciveness of innovation to export performance.

process, and the learning effect of exporting has been extensively researched in the literature (mostly empirically-led), in the context of firm's productivity/efficiency gains (see Chapter 4, pp.156-162, for a more extensive review on the learning or productivity effect of exporting).

The conventional approach to testing this 'learning-by-exporting' hypothesis is to analyse performance-related variables (such as labour productivity, TFP, average variable costs and the alike) as proxies of a firm's learning behaviour. More recently, Salomon and Shaver (2005) advocate that using innovation as a measure of learning provides a "more direct appraisal of the phenomenon", and that firms can strategically access foreign knowledge bases and enhance innovation capabilities through engaging in exporting activities. Furthermore, they maintain that exporting is more than merely an activity to increase the firm's product market; it is an activity that may generate information for the firm to use to innovate. Therefore, exporting can be considered a strategic action whereby the firm can enhance its competitiveness.

For instance, in a particular context of East Asian latecomer firms in the electronics sector, Hobday (1995) illustrates the learning process driven by foreign consumer demand (and hence exports) by deploying a framework for analysing the nature, direction and determinants of a firm's accumulation of technological knowledge. This conceptual model provides a cumulative view of how learning develops in sequence, shifting from production to investment then to innovation capabilities. It also illustrates that there exists a general trend for firms to begin with straightforward tasks and then accumulate capabilities systematically in a path dependent, cumulative manner, with knowledge, technological know-how and skills systematically building on each other. In summary, Hobday's framework suggests that a firm's export orientation pulls forward their technology, allowing them to overcome difficulties such as the lack of user-product links enjoyed by leaders in the established international markets. Therefore, export demand acts as a focusing device for learning and forces the pace of progress.

Moreover, this positive impact of exporting on learning/knowledge accumulation is also documented in empirical evidence in at least two European countries. In an analysis of Belgium manufacturing firms, Cassiman and Veugelers (1999) find evidence of learning by exporting: higher ratio of exports to sales leads to higher probability to innovate. Using different measures of innovation in Spanish manufacturing firms, Salomon and Shaver (2005) also find that exporting is related to *ex post* increases in innovation as proxied by product innovations and patent applications. They further argue that the results on patent applications in Spain reveal firms might well use the knowledge acquired abroad to enhance their competitive position at home.

Given that causality can run in both directions, a two-way linkage between a firm's exporting and innovating activities has also been proposed and tested empirically [27]. In particular, based on an analysis of a panel of Spanish manufacturing firms for the period 1990-1999, Cassiman and Martinez-Ros (2004) are able to confirm this expected bi-directional relationship: innovation tends to be a very important driver of exports (particularly, product innovation activities positively affect a firm's export decision); in addition, export activity *per se* seems to advance a firm's innovativeness (with no differentiation between product and process innovations).

Evidence of a two-way causation seems to be more frequently captured in studies on emerging economies. This might be because such countries are particularly heterogeneous in both their technology stock and export status. Developing/less developed countries usually stand out to gain more from trade vis-à-vis their developed counterparts (where learning effects are likely to be less pronounced), as the theories of technology catching-up or economic convergence predict (e.g. Ben-David and Loewy, 1998; Guillen, 2001). For instance, findings based on firm-level data for manufacturing in Chile suggest that exports significantly increase technological innovations and innovation increases the probability to participate in export markets, but only in firms conducting intensive technological innovation (i.e. above a certain threshold level of innovation intensity), which is consistent with the RBV of firms and the notion of absorptive capacity (*c.f.* Alvarez, 2001). In addition, evidence from a large sample of Chinese manufacturing firms also confirms this reciprocal relationship between export intensity/growth and R&D (Zhao and Li, 1997). And

[27] The paucity of evidence on this hypothesis of a feedback relationship may be partly explained by the limitations of data as well as the econometric methods available to explore this causality issue.

more recently, for a smaller sample of Chinese industrial firms, Guan and Ma (2003) report an interdependent relationship between the total improvement of innovation capability in firms and their export growth.

Chapter 3: An Empirical Analysis of the Firm's Exporting and Innovation Orientations

This chapter seeks to provide empirical evidence on what are the most crucial factors determining the firm's exporting and innovation activities in the UK context. With respect to the econometric modelling of the firm's export or innovation behaviour, the estimation techniques usually employed in the literature fall into three categories, viz. single-equation models, two-stage models, and more recently, the quasi-likelihood estimation method. This introductory section compares the merits and caveats of these modelling techniques.

To begin with, a logistic or probit model can be used to test the determinants of whether a firm undertakes exporting or innovating activity or not, where a binary dependent variable (indicating whether the firm engages in such activity) is regressed on a series of postulated variables that are argued to impact the firm's decision (to enter export markets or undertake innovative activity). Alternatively, some studies have employed the standard OLS approach to consider the determinants of the intensity of such an activity (often defined as export volume or R&D expenditure over total sales). In this case of estimating intensity, as the dependent variable is only observed if it is greater than zero, the analysis is often restricted to only those firms that export or innovate. No matter whether non-exporting or non-innovating firms are included or not, the OLS approach is very likely to yield biased results since the decision on how much to export or innovate is conditional on the decision to engage in such activity in the first instance. Put another way, those that export or innovate do not constitute a random sample of all firms that could potentially involve in such activity. The OLS method therefore confronts the standard 'sample selection' problem that often occurs in the evaluation literature (see end of this introduction for solutions to selectivity issues).

Consequently the Tobit modelling approach has also been adopted to include the information available both on a firm's probability to export/innovate and its exporting/innovating intensity. Moreover, this approach also utilises all the available information conveyed in the explanatory variables, including those for which the dependent variable is zero (i.e. non-exporters/non-innovators). It follows that the Tobit method is generally more favoured over the probit or OLS approach, as it allows the dependent variable to have a censored distribution (see, for instance, Kumar and Siddharthan, 1994).

Using a generalised Tobit approach, the expected value of the dependent variable with respect to each explanatory variable could be decomposed into two elements – the probability that an observation will be positive (i.e. the firm exports/innovates) as well as the conditional mean of dependent variable (i.e. the intensity). Nevertheless, one major issue that this approach fails to account for is the possibility that the explanatory variables may have different effects on the entry and intensity decisions, which are, after all, very distinct decisions made at rather different stages of the firm's growth trajectory. Taking exporting behaviour for instance, the decision to enter export markets and the decision as to how much to export conditional on this entry may be affected by two different sets of factors, and even for the same factors, the magnitude of their impact could vary between two stages. It follows that notwithstanding the superiority of the Tobit approach to other single-equation methods, this procedure is still too restrictive in that it requires the propensity equation and the intensity equation to have the same parameterisation (i.e. all determinants having identical effects on both decisions), which may again result in misspecification of the model (Cragg, 1971)[28].

However, this constraint may be relaxed by treating the issue as involving two equations (*c.f.* in the context of modelling of innovation, Bishop and Wiseman, 1999, provide a discussion of the merits of two-stage models over single-equation ones). Cragg (1971) has proposed a two-stage specification of the Tobit model to combat this restriction of parameters, where the probability of a non-limit outcome is determined independently of the level of the non-limit outcome. The first stage of this framework involves estimating a Probit model that utilises the data of all firms and centres on the first-stage decision to participate in exporting or innovation. As for the second stage, only the subset

[28] Lin and Schmidt (1984) later have proposed a procedure to test the validity of the restriction imposed by the Tobit regression against the alternative unrestricted form. Taking the estimation of exporting as an example, this method involves the estimation of three equations separately, viz. a truncated regression model for export intensity on exporters only, and Probit and Tobit models on all firms for probability to export and export intensity respectively.

of firms that sell abroad or innovate are taken into account. A truncated estimation approach is used here as the dependent variable is observed only if it is greater than zero (i.e. participation) (for instance, Wagner, 1996; Wakelin, 1998; Sterlacchini, 1999; Bleaney and Wakelin, 2002; Roper and Love, 2002).

Scholars opting for this dual treatment emphasise the importance of a distinction between the probability to export/innovate and the intensity of exporting/innovation; this takes into account the different impacts of a set of variables on various dimensions of exporting/innovating activities. Advocates of this two-stage framework include Wagner (1996), Wakelin (1998), Basile (2001), Bleaney and Wakelin (2002), Cassiman and Martinez-Ros (2003), Gourlay and Seaton (2004) and Lopez Rodriguez and Garcia Rodriguez (2005).

It is worth noting that Cragg's modified Tobit model is based on the underlying assumption that the two stages are independent of each other (i.e. the disturbances in the latent regression underlying the Probit model are not correlated with those in the truncated regression). If this crucial assumption fails to hold, the resulting truncated estimates will provide biased parameter estimates as far as the second-stage model (i.e. intensity) is concerned.

In addition, a method of simultaneous estimation has also been proposed to take into account the endogeneity of exporting and R&D decisions in modelling innovating/exporting behaviour. This involves the estimation of simultaneous probit models that treat exports and R&D as jointly endogenous variables. For instance, using a technique first devised by Maddala (1983), it is possible to regress the endogenous variables on the entire set of assumed exogenous variables and construct the predicted variables as instruments. In the second stage, export and innovation variables need to be replaced with these instruments to yield unbiased estimates of the impact of innovation on exports (and vice versa). Similar simultaneous approaches have been employed in several empirical studies treating innovation and exports as inextricably interdependent (Hughes, 1986; Zhao and Li, 1997; Smith *et al.*, 2002; Cassiman and Martinez-Ros, 2004; and Lachenmaier and Woessmann, 2006). Nevertheless, it is worth noting that this simultaneous approach is often confined to estimating the participation decision only, without accounting for the firm's performance in such activity (as measured by export/R&D intensity) conditional on participation.

Contrary to the two-stage approach differentiating firm's export/innovation decision from the magnitude of exports/innovations, some scholars also advocate for the inseparability of the two outcomes and therefore a quasi-likelihood estimation method – the fractional response variable approach as developed by Papke and Wooldridge (1996). Taking exporting activity for instance, this argued interdependence between two decisions arises from the *ex ante* nature of the export decision, where exporters cannot ascertain whether costs are sunk and therefore non-recoverable (Hanley, 2004). The firm will only participate in export markets, if the product price can cover the average total costs of exports (i.e. both variable and fixed costs). Once it starts exporting, these fixed costs become *ex post* sunk costs (whereas *ex ante* they are not). For instance, based on the *ex post* nature of sunk costs, Wagner (2001) argues there is no such a thing as a two-step decision – the firm's decision to export and how much to export are not mutually exclusive, as costs are carefully considered when firms decide whether it is profitable to participate in such export markets or not by producing the profit maximising quantity at the given price. In this sense, Hanley (2004) estimates two decisions in a single model, employing this quasi-likelihood estimation technique for fractional response variables ranging from zero to unity.

Appealing as it looks, the fractional variable approach still fails to acknowledge the possibility that the two decisions could be driven by two distinct sets of factors; and that even the same factor might have differing impacts on the firm's participation and then performance conditional on such participation (which is clearly evident in the findings provided in this chapter).

By relaxing this restriction of identical parametisation whilst still emphasising the inseparability between two decisions, the sample-selection model estimates the two decisions simultaneously allowing the error terms in two stages to be interdependent. Such a model recognises that those that export/innovate are not a random sub-set of all firms; rather, modelling export/R&D intensity (exports/R&D per unit of sales) needs to take into account that those with non-zero exports/R&D levels have certain characteristics that are also linked to how much is invested in exports/R&D. Failure to take into account this self-selection element when modelling the intensity equation would lead to results that suffer from selection bias.

Heckman (1979)'s procedure is one of the most advocated examples of this type of selection model. This method is based on the idea that export/innovation intensity is only observed if some criteria (defined with respect to a different set of variables) can be met. In essence, the Heckman procedure involves estimating two equations: in the first stage, a binary variable determines whether or not the outcome is observed; secondly, the expected value of the outcome is estimated, conditional on it having been observed. In other words, the first stage is to estimate a model of what determines whether exporting/R&D is undertaken or not (thus a 0/1 limited dependent variable model is estimated); the second stage then estimates how much is spent on exports/R&D per unit of sales, conditional on stage one. Note, maximum likelihood estimators have to be employed to obtain both efficient and consistent coefficients (empirically, see Barrios *et al.*, 2003, for example). That is, it is not efficient to estimate the probit model, and then the second-stage model conditional on the results from the probit model. Both models must be estimated simultaneously (using for example, FIML estimator) [29]. It follows that this is the approach to be adopted in subsequent empirical analyses in this chapter.

3.1 The Matched CIS3-ARD Dataset

The ability to undertake a micro-level analysis of the determinants of exporting/innovation, with particular focus on their inter-relationship, depends on the data available. There are 2 major micro-based sources of data that are appropriate, both of which include establishment-level data for the UK: i) the Community Innovation Survey 2001 (*CIS3*); and ii) the data for the year 2000 from the Annual Respondents Database (*ARD*). Ancillary information (particularly on ownership and spatial characteristics) available in the *ARD*, has been merged into the *CIS3* data for use in the subsequent analysis of what determines

[29] That is, stages 1 and 2 are estimated simultaneously using a FIML estimator since this is more efficient than using a two-stage approach. But the principle of the approach (and early implementation procedures after it was first introduced in 1979) is based on a two-stage procedure.

exporting/innovation. A more extensive description of the *CIS3* and *ARD* data as well as details of merging these two datasets can be found in the Appendix to this chapter (pp.136-140).

Table 3-1: Variable definitions used in the *CIS3-ARD* merged dataset for 2000

Variable	Definitions	Source
Export	Whether the establishment sold goods and services outside the UK (coded 1) or not in 2000	CIS3
Export intensity	Establishment export sales divided by total turnover in 2000	CIS3
R&D	Whether the establishment undertook any R&D as defined in the text (coded 1) or not in 2000	CIS3
R&D continuous	Whether the establishment undertook R&D continuously (coded 1) or not during 1998-2000	CIS3
Size	Number of employees in the establishment, broken down into 5 size-bands, i.e. 0-9, 10-19, 20-49, 50-199 and 200+	CIS3
Enterprise size	Number of employees in the enterprise	ARD
Age	Age of establishment in years (manufacturing only)	ARD
Employment	Current employment for establishment in 2000	ARD
Capital	Plant & machinery capital stock for establishment in 2000, manufacturing only (source: Harris and Drinkwater, 2000, updated) (£m 1980 prices)	ARD
Capital intensity	Capital/labour ratio, £'000 plant & machinery per worker in 1980 prices	ARD
Labour productivity	Establishment turnover per employee in 2000	CIS3
Multi-plant	Dummy coded 1 when establishment *i* belongs to a multiple-plant enterprise	ARD
>1 SIC multiplant	Dummy variable =1 if establishment belongs to a multiple-plant enterprise operating in more than 1 (5-digit) industry	ARD
>1 region multiplant	Dummy variable =1 if establishment belongs to multiple-plant enterprise operating in more than 1 UK region	ARD
US-owned	Dummy coded 1 if establishment *i* is US-owned	ARD
Other foreign-owned	Dummy coded 1 if establishment *i* is other-owned	ARD
Absorptive capacity (5 factors, see text for details)	AC for external knowledge	CIS3
	AC for national co-operation	CIS3
	AC for organisational structure & human resource management (HRM)	CIS3
	AC for international co-operation	CIS3
	AC for scientific knowledge	CIS3
Barriers to innovation[a] (10 factors identified in CIS)	Excessive perceived economic risks	CIS3
	High costs of innovation	CIS3
	Cost of finance	CIS3
	Availability of finance	CIS3
	Organisational rigidities within the enterprise	CIS3
	Lack of qualified personnel	CIS3
	Lack of information on technology	CIS3
	Lack of information on markets	CIS3
	Impact of regulations/standards	CIS3
	Lack of customer responsiveness	CIS3
Industry agglomeration	% of industry output (at 5-digit SIC level) located in local authority district in which establishment is located	ARD
Diversification	% of 5-digit industries (from over 650) located in local authority district in which establishment is located	ARD
Herfindahl	Herfindahl index of industry concentration (5-digit level)	ARD
Density	Population density in 2001 in local authority district in which establishment is located	CoP, 2001
Industry	Dummy variable =1 if establishment located in particular industry SIC (2-digit)	CIS3
GO regions	Dummy variable =1 if establishment located in particular region	CIS3
Greater South East	Dummy variable =1 if establishment belongs to enterprise operating in Greater South East region	ARD

[a] Each dummy variable is coded 1 if the barrier is of medium-to-high importance to the establishment.

Table 3-1 sets out the list of variables used in this chapter, along with the source of data. R&D spending is defined here as intramural R&D, acquired external R&D

or acquired other external knowledge (such as licences to use intellectual property [30]. Of particular importance is the absorptive capacity of the establishment. No direct information on this variable is available, but *CIS3* does contain information on key elements of organisational, learning and networking processes that can be related to absorptive capacity, i.e. external sources of knowledge or information used in technological innovation activities and their importance[31]; partnerships with external bodies on innovation co-operation[32]; and the introduction of changes in organisational structure and HRM practices which will be related to internal capabilities and thus (internal aspects of) absorptive capacity[33].

In order to extract core information, a factor analysis (principal component) was undertaken using the 36 relevant variables covering the above dimensions of absorptive capacity (for details see Table 3-2). Based on the Kaiser criterion (Kaiser, 1960), five principal components were retained (with eigenvalues greater than 1), accounting for some 62% of the combined variance of these input variables. In order to obtain a clearer picture of the correlation between those variables related to absorptive capacity and the five factors extracted, the factor loadings matrix was transformed using the technique of variance-maximising orthogonal rotation (which maximises the variability of the 'new' factor, while minimising the variance around the new variable). As can be see in Table 3-2, all 36 input variables used to measure absorptive capacity are supported by the Kaiser-Meyer-Olkin (hereafter KMO) measure of sampling

[30] There is other spending categorised in the CIS3 related to innovative activities, such as acquisition of machinery and equipment (including computer hardware) in connection with product and process innovation, but these are excluded from this narrower and more traditional definition of R&D being used here, after some initial analysis of the data and by comparing the CIS3 totals with those obtained from the other major source of micro data on R&D in the UK – Business Enterprise Research and Development (*BERD*) data. See http://www.berr.gov.uk/files/file9686.pdf for a copy of the CIS3 questionnaire.

[31] See question 12 in the CIS3 questionnaire. Table 3-2 lists the 16 variables included in CIS, and respondents were asked to rank how important each factor is (from 0 – not used, to 4 – high importance).

[32] See question 13.2 in the CIS3 questionnaire. Table 3-2 lists the 8 variables included in CIS. Since respondents were asked to indicate whether cooperation was with organisations that were 'local', 'national', 'European', 'US' or in 'Other' countries, cooperation could be separately identified at the national (which also includes local) and international level.

[33] See question 17.1 in the CIS3 questionnaire. Table 3-2 lists the 4 variables included in CIS, which are ranked from 0 (not used) to 3 (high impact) to indicate its effect on business performance.

adequacy – most of the KMO values are above 90% and an overall KMO value of nearly 95% suggests a 'marvellous'[34] contribution of the raw variables.

[34] Historically, the following labels are given to different ranges of KMO values: 0.9-1 marvellous, 0.8-0.89 meritorious, 0.7-0.79 middling, 0.6-0.69 mediocre, 0.5-0.59 miserable, 0-0.49 unacceptable.

Table 3-2: Structure matrix of factor loadings: correlations between variables and varimax rotated common factors

Input Variables*	**Factor 1** External knowledge	**Factor 2** National co-operation	**Factor 3** Organisational structure & HRM	**Factor 4** International co-operation	**Factor 5** Scientific knowledge	**Kaiser-Meyer-Olkin Measures**†
Sources of knowledge/info for innovation						
Suppliers	***0.814***	0.039	0.163	0.075	-0.068	0.983
Clients/customers	***0.825***	0.064	0.185	0.095	-0.033	0.961
Competitors	***0.818***	0.058	0.159	0.056	-0.028	0.965
Consultants	***0.791***	0.052	0.139	0.037	0.004	0.982
Commercial labs/R&D entreprises	***0.822***	0.090	0.072	0.044	0.122	0.971
Universities/other HEIs	***0.798***	0.124	0.076	0.041	0.136	0.960
Government research organisations	***0.858***	0.066	0.028	-0.051	0.115	0.952
Other public sectors	***0.824***	0.064	0.079	-0.027	0.056	0.975
Private research institutes	***0.843***	0.081	0.046	-0.037	0.110	0.969
Professional conferences	***0.818***	0.067	0.167	0.063	0.038	0.979
Trade associations	***0.846***	0.039	0.112	0.022	-0.014	0.976
Technical/trade press	***0.853***	0.041	0.153	0.028	-0.018	0.970
Fairs/exhibitions	***0.821***	0.038	0.166	0.077	-0.022	0.983
Technical standards	***0.837***	0.051	0.170	0.066	-0.006	0.985
Health &safety standards	***0.837***	0.053	0.113	0.034	-0.015	0.923
Environmental standards	***0.840***	0.054	0.108	0.037	0.004	0.930
Areas of changes of business structure and HRM practices						
Corporate strategies	0.260	0.060	***0.814***	0.048	-0.001	0.919
Advanced market techniques	0.270	0.029	***0.789***	0.016	0.037	0.926
Organisational structures	0.243	0.053	***0.795***	0.024	0.040	0.922
Marketing	0.282	0.064	***0.770***	0.030	0.001	0.937

Notes: *Factors extracted using principal-component method (5 factors retained) in conjunction with weighting, then rotated using orthogonal varimax technique; †Kaiser-Meyer-Olkin measure of sampling adequacy is employed to assess the value of input variables.

Table 3-2 (cont.)

Input Variables	**Factor 1** External knowledge	**Factor 2** National co-operation	**Factor 3** Organisational structure & HRM	**Factor 4** International co-operation	**Factor 5** Scientific knowledge	**Kaiser-Meyer-Olkin Measures**†
Co-operation partners on innovation activities (national/international)						
Suppliers (national)	0.137	***0.666***	0.049	0.332	-0.127	0.912
Suppliers (international)	0.100	0.191	0.059	***0.716***	0.088	0.895
Clients/customers (national)	0.132	***0.678***	0.093	0.349	-0.082	0.910
Clients/customers (international)	0.090	0.257	0.062	***0.686***	***0.215***	0.890
Competitors (national)	0.077	***0.717***	0.049	0.099	-0.097	0.864
Competitors (international)	0.061	0.251	0.027	***0.435***	***0.215***	0.886
Consultants (national)	0.107	***0.683***	0.054	0.201	0.058	0.930
Consultants (international)	0.038	0.040	-0.008	***0.550***	0.153	0.840
Commercial labs/R&D entreprises (national)	0.089	***0.636***	0.039	0.068	***0.251***	0.929
Commercial labs/R&D entreprises (international)	0.052	0.142	0.049	***0.393***	***0.581***	0.879
Universities/other HEIs (national)	0.127	***0.592***	0.084	0.110	***0.228***	0.875
Universities/other HEIs (international)	0.060	0.070	0.060	***0.314***	***0.628***	0.818
Government research organisations (national)	0.088	***0.668***	0.013	-0.105	***0.394***	0.853
Government research organisations (international)	0.052	0.183	-0.001	0.017	***0.749***	0.766
Private research institutes (national)	0.076	***0.683***	0.029	-0.109	***0.278***	0.876
Private research institutes (international)	0.041	0.029	0.050	***0.286***	***0.483***	0.792
No. of Observations						8109
LR test: independent vs. saturated: $\chi^2(630)$					2.0e+05	
Overall KMO						0.949

Based on the correlations between these 36 underlying variables and the five varimax-rotated common factors in Table 3-2 (each with a mean of zero and a standard deviation of 1), it is possible to interpret these factors as capturing the establishment's capabilities of exploiting external sources of knowledge; networking with external bodies at the national level; implementing new organisational structures and HRM strategies; building up partnerships with other enterprises or institutions at the international level; and acquiring and absorbing codified scientific knowledge from research partners respectively[35]. Here one could expect the absorptive capacity for scientific knowledge to be particularly important in indicating the technological opportunities an establishment possesses, as the notion of "technological opportunities" was originally put forward to reflect the richness of the scientific knowledge base (Scherer, 1992). Moreover, as research grows increasingly expensive and risky nowadays, industry has sought for specialist technology in academia or other government research institutes to complement or substitute their in-house R&D efforts drawing on its own resources.

Various hypotheses on the components of absorptive capacity have been put forward in the literature (particularly, in management studies), such as, human capital, external network of knowledge and HRM practices as in Vinding (2006) and potential and realised absorptive capacity as re-conceptualised by Zahra and George (2002). Nevertheless, there seems to be an imbalance between the relative abundance of various definitions of absorptive capacity and a deficiency of empirical estimates of this concept, with R&D-related variables most commonly used as proxies (e.g. Cohen and Levinthal, 1990; Arora and Gambardella, 1990; Veugelers, 1997; Becker and Peters, 2000; Cassiman and Veugelers, 2002; Belderbos *et al.*, 2004)[36]. However, given the path-dependent nature of absorptive capacity, R&D fails to capture the realisation and accumulation of absorptive capacity, not to mention its distinct elements[37]. As

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[35] The correlations with the highest values for each factor have been highlighted (using bold, italicised values) to provide evidence as to why a particular factor is interpreted as representing a specific aspect of absorptive capacity.

[36] Other empirical proxies of absorptive capacity include human capital measures (Romijin and Albaladejo, 2002; Vinding, 2006); while Schmidt (2005), includes diverse measures of knowledge management (i.e. absorptive capacity for intra-industry, inter-industry and scientific knowledge).

[37] See for instance, the arguments in Schmidt (2005). Note also, absorptive capacity is treated as predetermined in the estimated models (unlike R&D which is allowed to be potentially

far as this thesis is concerned, the approximation of absorptive capacity used here provides the most direct and comprehensive set of empirical measures available for the UK[38].

Others have taken a different approach with regard to how the above variables used to measure 'external' absorptive capacity should be classified. For example, Dachs *et al.* (2004) use the information on sources of knowledge from suppliers and customers to compute a variable that attempts to capture vertical spillovers (of knowledge). They obtain measures of horizontal spillovers based on how important information was from competitors; institutional spillovers using knowledge emanating from universities and research institutes; and lastly, public spillovers based on the importance of professional conferences and journals, as well as fairs and exhibitions as information sources.

A different approach is taken here. The pragmatic reason is that in the ensuing statistical analyses in this chapter, these spillover measures are found to be insignificant in determining exporting or R&D, whereas measures of absorptive capacity are found to be important determinants. Secondly, and linked to the insignificance of these spillover measures, the proportion of establishments that stated that such sources of knowledge had 'high' importance are relative small (15.1% for vertical spillovers; 3.5% for horizontal spillovers; 1.3% for institutional spillovers; and 4.5% for public spillovers). In contrast, the absorptive capacity measures are based on much more information and span a greater range (rather than, say, over 90% of establishments having a zero value for spillovers). Lastly, there is a high correlation between these types of spillover measures and the measures of absorptive capacity used here. Given the relationships between spillovers of knowledge (as measured above) and the measurement of absorptive capacity here, it is clear that knowledge-spillover effects will be captured within the absorptive capacity measures used in this analysis. Indeed, by definition

endogenous). This is because of its 'path-dependent' nature, which supposes that such capacity takes a (relatively) long time to build.

[38] In a study of the impact of technological opportunities on innovation activities of German firms, Becker and Peters (2000) also undertake factor analysis to construct proxies for technological opportunities but narrowly focusing on the opportunities stemming from scientific research. Likewise, in Nieto and Quevedo (2005), their measure of absorptive capacity is also built on a set of factors but only a single index is constructed.

absorptive capacity captures the ability of establishments to internalise external knowledge spillovers.

Most other variables included in Table 3-1 are self-explanatory. In particular, industrial agglomeration is included to take account of any Marshall-Romer external (dis)economies of scale (David and Rosenbloom, 1990; Henderson, 2003). The greater the clustering of an industry within the local authority in which the establishment operates, the greater the potential benefits from spillover impacts. Conversely, greater agglomeration may lead to congestion, and therefore may lower productivity. The diversification index is included to pick up urbanisation economies associated with operating in an area with a large number of different industries. Higher diversification is usually assumed to have positive benefits to producers through spillover effects. Specifically, agglomeration was measured as the percentage of industry output (at 5-digit SIC level) located in the local authority district in which the establishment was located; diversification was measured as the number of 5-digit industries (over 600) located in the local authority district in which the establishment was located. The Herfindahl index of industrial concentration is measured at the 5-digit 1992 SIC level to take account of any market power effects (which are expected to be associated with the propensity to undertake both exporting and R&D). The variable that measures if the establishment belongs to an enterprise operating in more than one (5-digit) industry (>1 SIC multiplant) is included to proxy for any economies of scope.

3.2 Determinants of Exporting Activities

3.2.1 Exporters vs. Non-exporters: Some Basic Characteristics

This section presents some basic comparisons between exporters and non-exporters and some establishment-level characteristics, before obtaining multivariate modelling results in the following section. Note all data are weighted [39] to ensure that it is representative of the UK distribution of

[39] Weights used are those available in the CIS3 dataset, rather than the *ARD*, as the latter is merged into the *CIS* data.

establishments (i.e. it is not biased towards the *CIS3* sample that was drawn, which over-represents larger establishments).

Table 3-3: Export proportion and intensity in UK establishments, 2000, by industry

Industry (1992 2-digit SIC)	proportion of exporters, %	exports/sales, %
Manufacturing		
Mining & quarrying (10-14)	22.0	5.6
Food & drink (15)	37.3	7.3
Textiles (17)	62.1	14.0
Clothing & leather (18)	28.5	5.6
Wood products (20)	22.9	3.1
Paper (21)	43.6	6.4
Publishing & printing (22)	20.4	3.4
Chemicals (23-24)	73.7	26.4
Rubber & plastics (25)	55.9	10.5
Non-metallic minerals (26)	36.1	8.8
Basic metals (27)	69.8	18.7
Fabricated metals (28)	32.4	6.4
Machinery & equipment n.e.s. (29)	57.2	17.9
Electrical machinery (20-32)	67.7	25.4
Medical etc instruments (33)	63.9	23.2
Motor & transport (34-35)	55.3	18.7
Furniture & manufacturing n.e.s. (36)	39.7	8.6
Non-manufacturing		
Construction (45)	3.5	0.6
Wholesale trade (51)	36.3	6.8
Transport (60-62)	3.7	1.1
Transport support (63)	15.4	7.2
Post & telecom (64)	7.1	2.5
Financial (65-67)	10.2	3.7
Real estate (70)	0.5	0.0
Machine rentals (71)	5.5	0.9
Computing (72)	35.7	14.0
R&D (73)	54.7	31.5
Other business (74)	16.0	4.3
All sectors	26.1	6.8

Notes: figures are percentages.
Source: weighted data from *CIS3.* n.e.s. denotes ‘not elsewhere specified’.

Information on which firms are engaged in international activities (exporting, importing, trading/operating abroad), and which are not, is difficult to come by. For the US in 2000, Bernard *et al.* (2005) report that the number of firms that export and import comprise 3.1 and 2.2 per cent of all firms. Eaton and Kortum (2004) find that some 17.4 per cent of French manufacturing firms exported in 1986. Data for the UK is reported in the Table 3-3, showing that in 2000 just over 26 per cent of UK firms (employing 10 or more employees) exported (although nearly 44 per cent did so in the manufacturing sector and only some 15.6 per cent in non-manufacturing).

Within industry sectors[40], exporting activity is much more prevalent in certain manufacturing sectors such as *chemicals* (74%), *basic metals* (70%), *electrical machinery* (68%) and *medical and other precision instruments* (64%); in contrast exporting is very low in the *real estate sector* (0.5%), *construction* (3.5%), *transport* (3.7%) and *machine rentals* (5.5%)[41].

Table 3-3 also shows that most establishments that export did not specialise exclusively on supplying overseas markets; in other words, export intensity – exports per unit of total sales – is significantly smaller than the proportion of establishments that exported some of their produce.

Table 3-4: Exporting proportion and intensity in UK establishments, 2000, by government office region

Region	Manufacturing		Non-manufacturing	
	proportion of exporters, %	Export intensity, %	proportion of exporters, %	Export intensity, %
East Midlands	45.7	9.8	16.0	3.0
Eastern	49.8	13.1	18.5	4.4
London	35.0	10.4	20.5	7.2
North East	40.3	12.5	10.4	2.1
North West	46.0	10.9	14.4	3.3
Northern Ireland	61.3	18.3	18.4	5.4
South East	43.9	12.6	23.6	6.5
South West	39.4	11.6	8.5	2.0
Scotland	42.5	13.7	13.3	3.6
West Midlands	48.3	9.5	17.0	3.5
Wales	47.2	14.0	10.8	2.0
Yorks-Humberside	40.5	9.4	16.1	2.1
All	43.9	11.8	15.6	3.9

Notes: figures are percentages.
Source: weighted data from *CIS3*

Table 3-4 presents data on exporting by Government Office region. In terms of the manufacturing sector, Northern Ireland has the highest percentage of establishments that export (61%) and a higher export intensity (18.3% of sales are sold outside the UK), while London has the fewest proportion of its establishments engaged in exporting (35%) and a much lower level of export intensity (10.4%). When non-manufacturing is considered, regional rankings are very different with London and the South East having a higher percentage of

[40] Note CIS3 does not cover ever industry sector; for example, it excludes retail trade. The full list is given in Table 3-3.

[41] An analysis of variance F-test of no association between industry and exporting (intensity) is significantly rejected at better than the 1% level.

establishments that export (20.5% and 23.6%, respectively), while the South West has the lowest proportion with only 8.5% of non-manufacturing establishments engaged in exporting[42].

Table 3-5: Export proportion and intensity in UK establishments, 2000, by size

Employment size	Manufacturing		Non-manufacturing		Total	
	proportion of exporters, %	exports/sales, %	proportion of exporters, %	exports/sales, %	proportion of exporters, %	exports/sales, %
0-9	21.7	6.4	9.2	3.7	12.2	4.4
10-49	36.7	8.7	15.4	3.8	22.9	5.5
50-249	64.2	18.4	21.9	4.7	42.6	11.5
250+	72.5	25.9	25.3	4.4	51.5	16.4
Total	43.9	11.8	15.6	3.9	26.1	6.8

Notes: figures are percentages.
Source: weighted data from *CIS3-ARD*

Table 3-5 shows that exporting increases with establishment size (especially in the manufacturing sector with almost three-quarters of establishments employing 250 or more workers engaged in exporting). Table 3-6 divides establishments into those that export and those that do not (separately for the manufacturing and non-manufacturing sectors), and reports the mean values of the majority of variables that will be used in modelling the determinants of exporting. Thus it shows significantly different means between exporters and non-exporters in terms of the 5 absorptive capacity indices obtained (using 36 variables covering internal and external aspects of absorptive capacity). For instance, manufacturing establishments that exported had an average value of 0.39 while those not exporting had a mean of -0.06 on their capacity for absorbing external knowledge. Likewise, the means of exporting establishments are dramatically higher than those of non-exporting ones in terms of all other aspects of absorptive capacity. Thus these variables for absorptive capacity would seem to be highly relevant in explaining which establishments are able to overcome barriers to entry in export markets (although it will only be possible to

[42] For manufacturing, the analysis of variance F-test of no association between region and whether establishments exported is significantly rejected at better than the 1% level; for exporting intensity rejection is at the 7% level. For non-manufacturing, rejection of the null is significant at better than the 1% level for exporting and exporting intensity.

ascertain the strength of the relationship between absorptive capacity and the propensity to export when considering it in a multivariate statistical model that controls for other covariates).

Table 3-6: Mean values of certain characteristics of UK establishments that exported or not, 2000

Variables	Manufacturing			Non-manufacturing		
Export =	yes	no	total	yes	no	total
Absorptive capacity (external knowledge)	0.39	-0.06	0.14	0.07	-0.12	-0.09
Absorptive capacity (national co-op)	0.12	-0.04	0.03	-0.01	-0.04	-0.03
Absorptive capacity (org structure & HRM)	0.24	-0.10	0.05	0.22	-0.08	-0.03
Absorptive capacity (international co-op)	0.23	-0.07	0.06	0.03	-0.06	-0.05
Absorptive capacity (scientific knowledge)	0.06	-0.05	0.00	0.03	-0.03	-0.02
R&D*	0.30	0.09	0.19	0.20	0.08	0.10
R&D continuous*	0.27	0.06	0.15	0.13	0.04	0.05
Labour productivity (£'000 turnover per worker)	100.48	158.55	132.87	1083.23	321.63	445.03
Capital/labour ratio	8.48	5.65	6.90	N/A	N/A	N/A
Age (years)	7.25	6.14	6.63	N/A	N/A	N/A
Herfindahl index	0.09	0.07	0.08	0.08	0.10	0.10
Industry agglomeration	2.09	1.34	1.67	1.04	0.73	0.78
Diversification	0.59	0.59	0.59	0.60	0.59	0.59
ln Density ('000 per hectare)	1.91	2.05	1.99	2.29	2.04	2.08
Single plant*	0.77	0.84	0.81	0.78	0.80	0.79
>1 SIC multiplant*	0.33	0.18	0.25	0.24	0.13	0.15
>1 region multiplant*	0.14	0.06	0.10	0.15	0.07	0.09
SE*	0.06	0.02	0.04	0.05	0.02	0.03
Received public support*	0.14	0.07	0.10	0.06	0.05	0.05
Foreign-owned*	0.04	0.01	0.02	0.03	0.01	0.01

See Table 3-1 for definitions. * denotes a dichotomous variable.

Notably, absorptive capacity is also very important in distinguishing between those non-manufacturing establishments that exported and those that sold domestically, although this variable seems to be less important outside manufacturing given its overall lower mean value.

Although the means of labour productivity also appear to be different in Table 3-6, a t-test on the equality of means indicates that there is no statistically significant difference in the mean values in this variable when considering those that export and those that do not, irrespective of whether they are in the manufacturing or non-manufacturing sector. Part of the reason is the influence of large outlier values in this variable, and perhaps also because present analysis has not controlled for other relevant covariates such as size and industry sector in Table 3-6.

Establishments that export are significantly more likely to engage in (continuous) R&D, which is true for both manufacturing and non-manufacturing, although the strength of the relationship again appears to be much stronger in the manufacturing sector.

Table 3-6 further shows that establishments that export are more likely to receive (usually financial) support from the public sector to help them with their innovation activities [43], especially manufacturing establishments. Such manufacturing establishments are shown to be more capital intensive and older. They also operate (on average) in more concentrated industries (i.e. those dominated by a smaller number of relatively larger establishments), which might suggest that in such industries there is more of a need to export to avoid oligopolistic market practices. Agglomeration economies seem to be more important for exporting establishments, but diversification in the local authority where they operate is not (on average) significantly higher or lower for establishments that export. In fact there is some evidence that exporters are more likely to operate in areas with lower population densities.

In contrast, in the non-manufacturing sector Table 3-6 shows that on average industry concentration is not significantly different between those that export and establishments that do not, while agglomeration is important (in much the same way as in manufacturing). However, although non-manufacturing exporters are statistically no more likely to operate in diversified areas, they are more

[43] In CIS3 information is available on a range of measures linked to public sector support for innovation-related activities (e.g. financial support from local, regional, and central government as well as the EU), as well as whether the establishment had participated in certain programmes (such as LINK, SMART, etc.).

likely to be associated with higher population density, which is different to the results obtained for the manufacturing sector.

Lastly, the results presented in Table 3-6 show that establishments are more likely to export if they belong to enterprises that also have production capacity in the Greater South East region (and this is important for both manufacturing and non-manufacturing establishments); they are less likely to export if they are also a single plant manufacturing enterprise; and they more likely to export if they belong to a multi-region and/or multi-plant firm, operate in more than one industry (thus gaining from economies of scope), and/or are foreign-owned.

In summary, this section provides some basic information on the characteristics of those establishments that export, as a backdrop to the statistical analysis on the determinants of exporting in the section that follows. Most of the results obtained equate with prior expectations relating to the importance of such variables and their expected link with exporting. Nevertheless, these (univariate) associations between exporting and various establishment characteristics do not take account of covariates (such as the size of the establishment or industry). Thus one reason for undertaking the (multivariate) statistical modelling in the ensuing section, *inter alia*, is to test whether these characteristics remain important in a multivariate setting.

3.2.2 Empirical Modelling

In modelling the determinants of exporting using the *CIS-ARD* merged dataset for 2000, separate models have been estimated for manufacturing and non-manufacturing (given the different export intensities between these two sectors). As discussed at the beginning of this chapter, the preferred estimation strategy is the Heckman approach to control for sample selectivity, allowing differing factors to determine two decisions whilst estimating both decisions simultaneously. Further technical details of this application of Heckman procedure in modelling exporting are provided in the Appendix to this chapter (pp. 140-141).

A first issue that needs to be tackled is that of identification in the Heckman model (i.e. which variables appear in the probit estimation but not in the sample selection equation). The approach employed here is a pragmatic one – a stepwise regression procedure that starts with a full list of variables in Table 3-1 retaining those in the model that have associated parameter estimates significant at the 10% level or better. This leads to certain variables only entering one part of the Heckman model, thus providing identification. For example, the capital/employment ratio, industry agglomeration, the Herfindahl index and the impact of regulations are only significant in the equation determining whether exporting takes place or not. Such variables are likely to be associated with breaking down barriers to entering export markets, rather than how much is exported (conditional on entering such markets), and as such the stepwise approach used here accords with *a priori* expectations.

Two versions of the Heckman model have been estimated: the first (denoted Model 1) takes no account of the likely endogeneity between exporting and R&D (i.e. the latter is assumed to be predetermined). Model 2 allows R&D to be endogenous, and replaces it with its predicted value obtained from the reduced-form model determining R&D (see Table 3-22 in the Appendix).

Manufacturing

The results for the manufacturing sector, in terms of whether establishments export or not, are provided in Table 3-7, with marginal effects reported[44]. The diagnostic tests provided in the lower part of the table show that the Heckman selection procedure is justified[45], since the correlation between the error terms of the two equations in the model is clearly large (ρ = -0.499) and statistically significantly different from zero (as tested using the reported likelihood ratio test of the null hypothesis that $\rho = 0$, with a $\chi^2(1) = 11.27$ value that is able to reject the null at better than the 1% significance level). A Smith-Blundell test for exogeneity has also been performed based on Model 2 (using the 'probexog' command in Stata), which includes all the (significant) variables in the model as

[44] Note, the *z*-values for Model 2 have not been corrected for bias that may result from using a generated variable (predicted R&D) based on the model estimated in Table 3-22. At the time of writing up this thesis, no software procedure is known to be able to do this, presumably because of the complexity of computing such 'correction factors'. Nevertheless, this bias is unlikely to be very large.

[45] An outline of the Heckman model, and thus definitions of the parameters ρ, σ and λ are provided in the Appendix (pp.140-141).

determinants of the probability of exporting and with R&D instrumented by those 8 variables highlighted in column 3 of Table 3-22 (e.g. the high cost of innovation). These instruments have been chosen on the basis of whether they are significant determinants of R&D (see Table 3-22) but not significant in determining whether the establishment exports (i.e. Model 2). The test obtained a $\chi^2(1)$ value of 22.6, which rejects the null of exogeneity at better than the 1% significance level.

Table 3-7: Determinants of exporting in UK manufacturing, 2000

Dependent variable: exporting undertaken or not	Model 1		Model 2		Means
	$\partial\hat{p}/\partial x$	z-value	$\partial\hat{p}/\partial x$	z-value	$(\bar{x})$
R&D	0.175	5.46	0.118	6.56	0.186
Establishment size					
20-49 employees	0.190	6.77	0.175	6.11	0.356
50-199 employees	0.310	10.42	0.284	9.57	0.215
200+ employees	0.373	10.07	0.357	10.31	0.074
ln enterprise size x Multi-plant	-0.016	-2.66	-0.013	-2.52	3.529
Absorptive capacity					
Absorptive capacity (external knowledge)	0.059	4.69	–	–	0.133
Absorptive capacity (national co-op)	0.028	1.86	–	–	0.029
Absorptive capacity (org structure & HRM)	0.041	3.58	0.021	1.94	0.057
Absorptive capacity (international co-op)	0.058	2.87	0.044	2.82	0.050
Absorptive capacity (scientific knowledge)	0.074	2.21	0.060	2.36	-0.007
Factors hampering innovation					
Impact of regulations	-0.092	-3.06	-0.077	-2.83	0.165
Other factors					
ln Capital/employment ratio (£m per worker ARD data)	0.026	2.58	0.020	2.09	-5.645
ln Labour productivity (£'000 per worker)	0.107	6.00	0.104	5.88	4.089
Industry agglomeration	0.008	2.01	–	–	1.456
ln Herfindahl index	0.074	4.51	0.074	4.88	-2.899
Industry sector (2-digit 1992 SIC)					
Food & drink	0.302	3.16	0.229	2.63	0.074
Textiles	0.512	11.00	0.477	9.18	0.040
Clothing & leather	0.377	4.19	0.336	3.78	0.032
Wood products	0.276	2.60	0.202	2.06	0.040
Paper	0.360	4.06	0.246	2.57	0.030
Publishing & printing	0.234	2.22	0.199	2.20	0.113
Chemicals	0.517	11.55	0.458	7.97	0.037
Rubber & plastics	0.504	9.06	0.431	6.54	0.065
Non-metallic minerals	0.322	3.16	0.282	2.97	0.033
Basic metals	0.506	10.58	0.455	7.71	0.027
Fabricated metals	0.438	5.17	0.377	4.75	0.186
Machinery & equipment nes	0.505	8.14	0.429	6.37	0.104
Electrical machinery	0.519	10.43	0.453	7.88	0.071
Medical etc instruments	0.500	10.30	0.472	9.36	0.035
Motor & transport	0.435	6.43	0.386	5.63	0.039
Furniture & manufacturing nes	0.433	6.06	0.372	5.22	0.067
Region					
Eastern England	0.073	1.82	–	–	0.086
Northern Ireland	0.254	3.63	0.236	3.43	0.020
ρ	-0.499	-4.07	-0.731	-8.30	
σ	1.725	25.66	1.920	20.21	
λ	-0.860	-3.59	-1.403	-6.01	
(unweighted) N	3303		3303		
N (export > 0)	1722		1722		
Log pseudo-likelihood	-3809.2		-3843.2		
Wald test of independent equations: $\chi^2(1)$	11.27		24.23		
Smith-Blundell test of exogeneity of R&D: $\chi^2(1)$			22.65		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of R&D (hence the predicted value is used based on the reduced-form model in Table 3-22. The reported parameter estimates are all statistically significant at the 10% level. Weighted regression is used with merged *CIS-ARD* data. For variable definitions, see Table 3-1.

An establishment undertaking R&D is associated with a significantly higher likelihood of non-zero exports, i.e. (*cet. par.*) a 17.5% higher probability of selling internationally when R&D is treated as exogenous. However, when R&D is allowed to be endogenous (and thus replaced with its predicted value), the marginal effect for this variable falls from 0.175 to 0.118. The final column in Table 3-7 shows that only some 18.6% of UK manufacturing establishments undertook R&D in 2000; thus, this had an important impact on the propensity to export. The parameter estimates for the remaining variables, which enter as determinants of whether exporting is undertaken or not, are mostly very similar for models 1 and 2. Thus, only those reported for Model 2 will be referred to, where R&D enters as an endogenous variable (i.e. the preferred model). The size of the establishment has a major impact on whether any exporting takes place; vis-à-vis the baseline group (establishments employing less than 10), moving to 20-49 employees increases the probability of exports > 0 by 17.5%, an increase in the probability by 28.4% in the 50-199 group and up to an increase of almost 36% for establishments with 200+ employees[46]. This confirms the results presented in Table 3-5 that size and the propensity to export are positively related. Given that the last column in Table 3-7 shows the distribution of establishments by size, it can be seen that the UK has relatively fewer establishments in the largest size bands listed, thus to some extent limiting the number of establishments that export. However, size of the enterprise is (*cet. par.*) negatively related to the probability of selling overseas if the establishment belongs to an enterprise that has multiple plants.

Overall absorptive capacity is found to be important in determining whether an establishment has non-zero exports in the manufacturing sector, but the variables representing the acquisition of external knowledge and national co-operation for innovation purposes become insignificant when R&D is treated as endogenous. This suggests that these aspects of absorptive capacity (which by construction are directly based on innovation activities) are important drivers of whether any R&D is undertaken, and then indirectly impact on whether the establishment exports through the inclusion of (endogenous) R&D in the

[46] It is likely that to some extent size and the propensity to export may be endogenous (e.g. for some firms exporting is a means for achieving growth and thus larger size, as domestic markets may be limited). This will result in some (unknown) likely upward bias in the estimated coefficients, but is unlikely to alter the result that there is a strong positive relationship between size and the ability of firms to overcome barriers to exporting.

exporting equation[47]. Establishments with higher levels of internal absorptive capacity (based on their organisational and HRM characteristics) are marginally more likely to overcome barriers into export markets; increasing this aspect of absorptive capacity by one standard deviation from its mean value increases the probability of exporting by over 2%. The ability to internalise external knowledge gained from international co-operation increases the likelihood of exporting by 4.4% (again based on one standard deviation increase), while absorbing scientific knowledge (from research organisations) results in an increase in the likelihood of selling overseas by around 6%. Here the relative magnitude of different dimensions of absorptive capacity is perhaps not surprising. From the perspective of technological opportunities, the science-based technological opportunities generally require a higher level of absorptive capacity than those generated by other sources of knowledge, such as suppliers and customers (Becker and Peters, 2000). Given that the largest absorptive capacity is likely to be called for to assimilate scientific knowledge stemming from research institutes (Leiponen, 2001), the absorptive capacity for this type of knowledge could therefore be expected to have the largest impact on establishment's internal capabilities (with respect to exporting in this context).

Establishments with higher labour productivity are also more likely to enter export markets; a doubling of this variable (from its mean value of just under £60k turnover per worker to just over £119k) increases the probability of exporting by some 7.2%[48]. More capital-intensive establishments are also more likely to export; doubling the capital-to-labour ratio (from a mean of just over £3.5k per worker in 1980 prices) increases the probability of exporting by about 1.4%. In all, these results confirm those often given in the literature that 'better' establishments (in terms of their ability to internalise external knowledge, productivity and capital intensity) are more likely to export.

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[47] This can also be seen by comparing the results for the structural equation (Model 2) in Table 3-7, and for the reduced-form model in Table 3-22.

[48] If the 'learning-by-exporting' hypothesis (*c.f.* Chapters 4 and 5) is correct, then labour productivity may also be (at least in part) endogenous. However, this potential endogeneity is not addressed here, due to lack of data to provide appropriate instruments. Nevertheless, this endogenous relationship is tested and confirmed in Chapter 5, where labour productivity is found to be significant in determining export propensity even after its endogenous nature has been taken into account.

The results in Table 3-7 also indicate that industry/market concentration is linked to a greater probability of exporting. Increasing the Herfindalh index of market concentration, from its mean value of 0.06 to 0.16 (the latter being the average value for the 90th decile group in manufacturing), raises the (*cet. par.*) probability of exporting by 7.3%. The impact of regulations as a barrier to innovation also reduces the likelihood of the establishment exporting (by some 7.7%). Lastly, sector also matters, with all those industries listed in the table having higher probabilities of exporting (by between 19.9 to 47.7%) vis-à-vis *mining & quarrying* (the baseline group). The industries with the highest propensities to export are (*cet. par.*) *textiles*, *chemicals*, *rubber & plastics*, *basic metals*, *machinery & equipment*, *electrical machinery and medical & precision instruments*. Establishments in Northern Ireland are more likely to engage in selling overseas, with a (*cet. par.*) 23.6% higher probability of exporting. There are no other significant 'regional effects' for the manufacturing sector.

None of the other variables tested (see Table 3-1) proves to be significant barriers to entry into export markets (e.g. age of the establishment, foreign ownership, industry diversification, whether the establishment belongs to an enterprise operating in more than one industry, more than one region, or in the Greater South East region).

In modelling how much of turnover is exported, the results for manufacturing are reported in Table 3-8, covering just those with positive export sales (given the 'two-stage' Heckman approach used, these results are conditional on the model determining whether exporting takes place at all). The models presented coincide with the treatment of continuous R&D as being either exogenous or endogenous (in a comparable way to how R&D is treated in Table 3-7). Again a Smith-Blundell test for exogeneity has been performed based on Model 2 (using the 'tobexog' command in Stata), which includes all the (significant) variables in the model as determinants of the intensity of exporting and with continuous R&D instrumented by those 15 variables highlighted in data column 5 of Table 3-22 (e.g. US-owned). These instruments are chosen on the basis of whether they are significant determinants of continuous R&D (see Table 3-22) but not significant in determining exporting intensity (i.e. Model 2). The test obtained an *F*-statistic of 106.4 (which rejects the null of exogeneity at better than the 1% significance level)[49].

Table 3-8: Determinants of exporting intensity in UK manufacturing, 2000 (cont.)

Dependent variable: *ln* exporting intensity	Model 1		Model 2		Means ($\bar{x}$)
	$\hat{\beta}$	*z*-value	$\hat{\beta}$	*z*-value	
R&D continuous	0.421	3.04	–	–	0.266
Establishment size					
10-19 employees	-0.348	-1.65	-0.652	-2.42	0.161
20-49 employees	-0.269	-1.92	-0.768	-2.80	0.362
50-199 employees	-0.245	-2.05	-0.908	-2.94	0.308
200+ employees	–	–	-0.748	-2.25	0.127
Absorptive capacity					
Absorptive capacity (national co-op)	-0.066	-2.10	–	–	0.113
Absorptive capacity (scientific knowledge)	0.054	2.21	0.064	2.28	0.052
Industry sector (2-digit 1992 SIC)					
Food & drink	-0.467	-2.03	–	–	0.062
Paper	-0.583	-2.05	–	–	0.030
Non-metallic minerals	0.603	2.29	0.763	2.66	0.028
Machinery & equipment nes	0.424	2.37	0.348	1.82	0.134
Electrical machinery	0.473	2.96	0.395	2.19	0.109
Medical etc instruments	0.394	1.95	–	–	0.052
Motor & transport	0.455	3.13	0.496	3.28	0.049
Region					
London	0.613	2.76	0.669	2.96	0.053
Northern Ireland	0.697	3.21	0.428	1.74	0.028
South West	0.351	1.97	0.369	2.06	0.068
Scotland	0.416	2.63	0.349	2.18	0.089
Wales	0.492	2.67	0.429	2.35	0.059
Smith-Blundell test of exogeneity of R&D continuous: F (1, 3298)			106.40		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of continuous R&D (hence the predicted value is used). All parameter estimates are statistically significant at least at the 10% level. Weighted regression is used with merged *CIS-ARD* data. Values of diagnostic tests are the same as in Table 3-7. For variable definitions, see Table 3-1.

In Model 1, undertaking continuous R&D is associated with an over 52% higher level of export intensity[50], but when continuous R&D is instrumented it is no longer statistically significant (rather, as discussed below, the importance of the size of the establishment on intensity increases significantly when the continuous R&D variable is omitted, suggesting a positive relationship between

[49] Again, as in Table 3-7, this test is only indicative.

[50] Since the dependent variable in the model is the natural log of export intensity, the elasticity with respect to a dichotomous variable is given by $\exp(\hat{\beta})-1$.

the undertaking of continuous R&D and the size of the establishment conditional on having controlled for entry into export markets).

While Table 3-7 shows that the size of the establishment has a major impact on whether any exporting takes place (i.e. the larger the establishment, the greater the probability of exporting, presumably reflecting the availability of necessary resources to overcome the fixed costs of internationalisation), Table 3-8 shows that conditional on having overcome such ‘entry barriers’ (and other covariates included in the model), establishments with more than 10 employees export less of their sales[51]. As with the results for export probability, the focus for interpretation here is on Model 2. For example, establishments employing between 10-19 employees (*cet. par.*) export nearly 48% less of their sales, and this rises to a nearly 60% lower export intensity for those employing 50-199 employees before falling back to almost 53% lower intensity for the largest establishments. This negative relationship between size and export intensity is consistent with the literature (cited earlier) that, conditional on entry into export markets, as the establishment grows larger (and presumably becomes more productive) it has an incentive to extend its foreign-market penetration through FDI (rather than exporting). Thus, it opens subsidiaries overseas, whereby (in part) they sell to the host country, leaving a greater proportion of output produced in domestic plants for domestic sales. Unfortunately, it is not possible to test the plausibility of such an explanation with the *CIS-ARD* data available, as there is no indication of whether the establishment belongs to a UK multinational enterprise (henceforth MNE). If such a marker for UK outward FDI existed, presumably including it would alter the negative size-intensity relationship obtained here.

Other variables that might have been expected to be important (see Table 3-1, such as labour productivity, most aspects of absorptive capacity and ownership)

[51] Estimating the intensity equation (for establishments where exporting is greater than 0) by OLS (and thus omitting the inverse-Mills ratio variable associated with the Heckman correction for sample selection) results in the negative relationship between size and intensity largely disappearing. When continuous R&D is exogenous, this variable has a value of 0.64, while the two variables ‘10-19 employees’ and ‘200+ employees’ have parameter estimates of -0.44 and 0.28, respectively (all *t*-values are greater than |2.6|). When continuous R&D is instrumented, it remains as statistically significant (with a value of 0.51), while only the ‘10-19 employees’ variable remains in the model (with an estimated parameter value of -0.37). This suggests i) that the negative relationship between size and export intensity is obtained only when conditioning on market entry; and ii) there is a strong positive relationship between size and continuous R&D, after conditioning on market entry.

are found not to be statistically significant in determining exporting intensity; only those with relatively higher levels of absorption of external scientific knowledge have higher intensities. Again, this might be explained by the fact that the absorptive capacity related to science-based knowledge reflects the highest level of technological opportunities as well as the strongest internal capability an establishment possesses.

As with the determinants of whether exporting occurs or not, sector also matters in explaining export intensity, with all those industries with positively significant parameter estimates having higher export intensities (by 42-114%). The industries with higher intensities cover *non-metallic minerals*, *machinery & equipment*, *electrical machinery*, *medical and precision instruments* and the *motor & transport sectors*.

The location of the establishment within the UK is also found to be a major determinant of export intensity (more so than as a determinant of entry into overseas markets – Table 3-7). Establishments located in London sell (*cet. par.*) over 95% more of their turnover overseas; those in Northern Ireland have a 53% higher export intensity; while establishments in the South West, Scotland and Wales, have higher intensities of 45%, 42% and 54%, respectively.

Non-manufacturing

As evidenced in Table 3-3, far fewer establishments are involved in exporting outside of the manufacturing sector with tradable services mostly concentrated in only a few industries, such as the *R&D* (SIC 73), *wholesale trade* (SIC 51) and *computing* (SIC 72) industries. The same Heckman sample selection model has been employed here for non-manufacturing, with the results provided in Table 3-9 and Table 3-10. Now turning to the results from estimating this model, the results relating to whether establishments export or not are provided in Table 3-9, with marginal effects reported[52].

[52] As before, a stepwise regression procedure was adopted with variables retained in the model that had associated parameter estimates significant at the 10% or better level.

Table 3-9: Determinants of exporting in UK non-manufacturing, 2000

Dependent variable: exporting undertaken or not	Model 1		Model 2		Means
	$\partial\hat{p}/\partial x$	z-value	$\partial\hat{p}/\partial x$	z-value	($\bar{x}$)
R&D	0.141	5.53	0.036	4.41	0.094
Establishment size					
20-49 employees	0.086	5.55	0.080	5.12	0.322
50-199 employees	0.108	4.96	0.097	4.52	0.136
200+ employees	0.233	5.52	0.207	4.82	0.031
ln enterprise size **X** Multi-plant	-0.021	-5.30	-0.022	-5.34	0.795
Other factors					
ln Labour productivity (£'000 per worker)	0.036	6.73	0.036	6.64	4.282
Industry agglomeration	0.006	3.07	0.006	3.09	0.784
ln Herfindahl index	-0.017	-2.58	-0.018	-2.77	-2.994
Operated in > 1 SIC	0.036	2.29	0.035	2.22	0.149
Multi-plant enterprise > 1 region	0.125	3.54	0.130	3.64	0.085
Industry sector (2-digit 1992 SIC)					
Wholesale trade	0.331	12.80	0.319	12.33	0.247
Transport support	0.151	3.41	0.159	3.50	0.040
Real estate	-0.087	-4.84	-0.089	-5.12	0.047
Computing	0.360	6.68	0.319	5.68	0.042
Other business services	0.194	8.08	0.177	7.17	0.244
Region					
South East	0.041	2.39	0.040	2.33	0.134
South West	-0.053	-3.04	-0.052	-2.96	0.077
ρ	-0.221	-1.49	-0.198	-1.26	
σ	1.861	28.02	1.867	28.12	
λ	-0.412	-1.44	-0.369	-1.23	
(unweighted) N	4007		4007		
N (export > 0)	749		749		
Log pseudo-likelihood	-3222.069		-3246.639		
Wald test of independent equations: $\chi^2(1)$	2.07		1.50		
Smith-Blundell test of exogeneity of R&D: $\chi^2(1)$			3.13		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of R&D (hence the predicted value is used based on the reduced-form model in Table 3-23). The reported parameter estimates are all statistically significant at the 10% level. Weighted regression is used with merged *CIS-ARD* data. For variable definitions, see Table 3-1.

Again, a Smith-Blundell test for exogeneity has also been performed based on Model 2, which includes all the (significant) variables in the model as determinants of the probability of exporting and with R&D instrumented by those 5 variables highlighted in column 3 of Table 3-23, such as 'received support from public sector'. These instruments have been chosen on the basis of whether they are significant determinants of R&D (see Table 3-23) but not significant in determining whether the establishment exports (i.e. Model 2). The test obtained a $\chi^2(1)$ value of 3.13, which rejects the null of exogeneity at 10% significance level.

As with the case of estimation for manufacturing, when R&D is treated as being exogenous to establishment's export decisions, the R&D-export relationship is over-estimated: undertaking R&D activity increases the probability to export by more than 14% in Model 1; whereas with the endogeneity being controlled for in Model 2, the effect of doing R&D on the probability of entering export markets reduces to less than 4%. The final column in Table 3-9 shows that only 9.4% of UK non-manufacturing establishments undertook R&D in 2000; thus, this low rate of investment in R&D might explain its less pronounced impact on the propensity to export. On the other side, the estimated coefficients of other covariates show broader similarity between the two models. Again, given the evidenced endogeneity in the R&D and exporting linkage, the results are interpreted on the basis of Model 2 where an instrumented R&D variable is incorporated[53].

In addition, the size of the establishment has a role in determining whether any exporting takes place: vis-à-vis the baseline group (establishments employing less than 10), an establishment with 20-49 workers (*cet. par.*) has a higher probability of exporting of some 8%, while there is an increase of over 20% for establishments with 200+ employees. Nevertheless, since there are only some 3% of all establishments with employment above 200 people in non-manufacturing sector, this influence of size on establishment's export orientation is unlikely to be large. In other words, only a minority benefit from economies-of-scale that help break down barriers to internationalisation in services-oriented industries. Therefore, on balance, the establishment size is significantly less important compared to its impact on the likelihood of exporting in the manufacturing sector as discussed before.

In addition to the establishment sizes, it is also possible to include the size of the enterprise for those establishments that belong to multi-plant enterprises (i.e. employment size for single-plant enterprises is already accounted for using the dummy variables for establishment size-band). Estimation results show that increasing the size of the enterprise is negatively related to the probability of selling overseas if the establishment belongs to an enterprise with multiple plants, suggesting that (having controlled for the large positive relationship

[53] As shown in Table 3-23, R&D dummy is instrumented using a dummy variable for size band 1 (10-19 employees); absorptive capacity for national cooperation; whether received public support; and some industry dummies.

between establishment size and exporting) large multi-plant enterprises have a slightly higher propensity to supply UK markets vis-à-vis single-plant enterprises. This small, negative impact of enterprise size is consistent with the results obtained from manufacturing sector, although it is considerably stronger there.

In non-manufacturing, establishments with higher (labour) productivity are also more likely to break down barriers to international markets although this effect is not particularly strong. Meanwhile, those belonging to part of enterprises that operate in more than one region and/or more than one industry have higher probability of exporting, with the 'multi-regional' effect being more significant – increasing the (*cet. par.*) likelihood of exporting by some 13%. Moreover, from the perspective of the industry/market characteristics, the degree of agglomeration tends have a positive impact on businesses going international, whilst the market concentration seems to negatively affect this internationalisation process (in contrast to its role in manufacturing sector), although both effects are rather marginal.

Most notably, the industry in which an establishment operates seems to be the most significant factor determining its decision to become global. The results show that the industries with the highest propensities to export are (*cet. par.*) *wholesale trade*, *computing*, *other business services* and *transport support*. The *real estate* sector is associated with an almost 9% lower probability of exporting.

As to location effects, establishments in the South West are more than 5% less likely to engage in selling overseas; while establishments in South East England are some 4% more likely to supply overseas markets. Overall, in line with results found in manufacturing, no strong regional effects are identified.

None of the other variables entered (see Table 3-1) prove to be significant barriers to entry into export markets for non-manufacturing establishments[54]. Some other establishment-specific characteristics that help overcome barriers to entering export markets in the manufacturing sector turn out to be statistically unimportant in the non-manufacturing sector. In particular, absorptive capacity

[54] Note, given that capital stock figures are not available for UK non-manufacturing sector, capital intensity could not be computed to test its impact on exporting in this sector, vis-à-vis in manufacturing.

is not significant in determining entry into foreign markets. In all, these results suggest that the ‘better’ establishments (in terms of their ability to appropriate internal and most importantly, external knowledge) are *not* particularly more likely to export in the non-manufacturing sector. This is in sharp contrast to the results obtained for manufacturing which are more consistent with conventional wisdom and the literature in this area (that the ‘better firms’ export) as reviewed in Chapter 2.

Table 3-10: Determinants of exporting intensity in UK non-manufacturing, 2000 (cont.)

Dependent variable: *ln* exporting intensity	Model 1		Model 2		Means ($\bar{x}$)
	$\hat{\beta}$	*z*-value	$\hat{\beta}$	*z*-value	
R&D continuous	0.574	2.92	–	–	0.130
Establishment size					
10-19 employees	-0.731	-2.72	-0.706	-2.66	0.252
20-49 employees	-1.034	-4.09	-0.991	-3.94	0.403
50-199 employees	-1.305	-4.79	-1.241	-4.59	0.195
200+ employees	-1.771	-5.81	-1.598	-5.44	0.057
Absorptive capacity					
Absorptive capacity (national co-op)	0.083	1.71	0.100	1.90	-0.012
Factors hampering innovation					
Organisational rigidities	0.531	2.00	0.527	2.00	0.065
Other factors					
Operated in >1 SIC	0.390	2.27	0.414	2.35	0.237
Multi-plant enterprise > 1 region	-0.438	-2.12	-0.464	-2.25	0.146
US-owned	1.900	5.48	1.822	5.46	0.009
Other foreign-owned	0.713	2.48	0.692	2.36	0.035
Industry sector (2-digit 1992 SIC)					
Transport	1.074	2.27	1.011	2.04	0.019
Transport support	1.981	7.04	1.966	6.79	0.038
Financial services	3.320	8.09	3.153	8.20	0.000
Computing	0.842	3.64	1.055	4.68	0.090
Other business services	0.637	2.97	0.688	3.07	0.237
Region					
London	0.484	2.35	0.419	2.05	0.177

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of continuous R&D (hence the predicted value is used). All parameter estimates are statistically significant at least at the 10% level. Weighted regression is used with merged *CIS-ARD* data. Values of diagnostic tests are the same as in Table 3-9. For variable definitions, see Table 3-1.

Turning to the results for non-manufacturing on what proportion of turnover is exported (in Table 3-10), it is important to emphasise again that the results for the export intensity equation are conditional on the model determining whether exporting takes place at all. As with manufacturing, after controlling for the endogeneity between R&D and exporting activities, undertaking R&D continuous no longer has a statistically significant impact on exporting intensity. Nevertheless, although absorptive capacity is not important in determining whether exporting takes place or not, conditional on having successfully internationalised, having higher absorptive capacity for national cooperation renders a noticeable increase to exporting intensity.

Notably, on the impact of establishment size, while Table 3-9 shows that the size of the establishment has a significant impact on whether any exporting takes place (particularly in larger establishments), Table 3-10 shows that conditional on having overcome ‘entry barriers’ (and the other covariates included in the model), establishments with more than 9 employees export considerably less of their sales. That is to say, establishments employing between 10-19 employees (*cet. par.*) export more than 50% less of their sales; those employing 20-49 employees export almost 63% less; the overseas sales are some 71% less in those with 50-199 employees; and this negative impact is highest for the 200+ size-band where exports are almost 80% lower (vis-à-vis the 0-9 employee size-band)[55]. Thus, the negative relationship between exporting intensity and establishment size is even more pronounced than in the manufacturing sector. Also in non-manufacturing, this relationship is strictly negative, with the smallest establishments more likely to export a larger proportion of their turnover when compared to medium- and large-sized companies. In manufacturing, the relationship is U-shaped, with establishments employing 200+ workers not experiencing lower export intensities.

The industry in which the establishment operates also matters in explaining export intensity, those industries with highest export intensity include *financial services*, *transport support*, *computing and transport*. Another major determinant of export intensity is the location of the establishment being in London, which is (*cet. par.*) associated with over 52% more turnover sold overseas.

Those non-manufacturing establishments that belong to enterprises operating in more than one SIC industry group (and thus benefiting from economies-of-scope) also have some 51% higher export intensities; whereas those as parts of enterprises located in at least two regions tend to export some 37% less of their total sales, which maybe explained by the associated domestic orientation of these multi-region firms. Non-manufacturing establishments that are US-owned have (*cet. par.*) a 5-fold higher level of exports per unit of total sales; those that are owned by companies with their headquarters in other foreign countries have an almost 100% higher export intensity. Thus, being foreign-owned in the non-manufacturing sector (which only a very limited number of establishments are) is associated with significantly higher levels of international sales.

[55] Since the dependent variable in the model is the natural log of export intensity, the elasticity with respect to a dichotomous variable is given by $\exp(\hat{\beta}) - 1$.

Rather unexpectedly, amongst those establishments that report organisational rigidities within the enterprise as a factor hampering their innovation ability, there is an almost 70% higher level of exports per unit of total sales. Other establishment-specific variables (see Table 3-1) that might have been expected to be important (such as labour productivity, R&D activity, etc.) are found not to be statistically significant determinants of exporting intensity. Rather, the size-bands, industry and foreign-ownership characteristics are the most crucial factors, conditional on the establishment having overcome barriers to exporting.

3.2.3 Conclusions

This first part of the chapter has deployed establishment-level data from the 2001 Community Innovation Survey (with some additional – mostly ownership and location – variables added from the Annual Respondents Database) for the UK, to examine what are the critical factors determining micro exporting behaviour.

Starting with some basic information on the characteristics of exporting establishments using the *CIS* data, the beginning of this chapter (pp. 83-89) shows that in 2000 just over 26 per cent of UK establishments (employing 10 or more employees) exported (although nearly 44 per cent did so in the manufacturing sector and only some 15.6 per cent in non-manufacturing). Within industry sectors, exporting activity is much higher in *chemicals*, *basic metals*, *electrical machinery* and *medical and other precision instruments*; in contrast exporting is very low in the *real estate sector*, *construction*, *transport and machine rentals*. Moreover, most establishments that export do not specialise exclusively on supplying overseas markets (i.e. export intensity is significantly smaller than the proportion of establishments that export some of their produce).

Geographically, across Government Office regions, in the manufacturing sector Northern Ireland has the highest percentage of establishments that export and higher export intensity; London has the smallest proportion of its establishments engaged in exporting and a much lower level of export intensity. When non-manufacturing is considered, regional rankings are very different with London and the South East having a higher percentage of establishments that export. Also importantly, exporting increases with establishment size, especially in the manufacturing sector; for instance, nearly three-quarters of establishments employing 250 or more workers were engaged in exporting during the period observed.

In terms of the variables that are argued to be determinants of exporting in the literature and that are available in the *CIS-ARD* dataset (thus empirically tested in the ensuing sections), initial inspection of exporters and non-exporters has suggested that -

- Absorptive capacity is much higher in those establishments that export (especially in the manufacturing sector);
- establishments that export are significantly more likely to engage in (continuous) R&D and to be innovative (as measured by whether they produced new product and/or process innovations, whether novel or otherwise);
- establishments (particularly in the manufacturing sector) that export are much more likely to co-operate with others (especially overseas partners) in their innovative activities;
- establishments that export are more likely to receive support from the public sector;
- the proportion of establishments engaged in exporting is greater when labour productivity is higher;
- manufacturing establishments that export are shown to be older, more capital intensive and (on average) operate in more concentrated industries (i.e. those dominated by a smaller number of relatively larger establishments);
- agglomeration economies seem to be more important for exporting establishments, but diversification in the local authority where they operate is not (on average) significantly higher or lower for manufacturing establishments that export (but it is for non-manufacturing);
- there is some evidence that manufacturing exporters are more likely to operate in areas with lower population densities, while non-manufacturing exporters operate in diversified areas with higher population density;

- lastly, establishments are more likely to export if they belong to enterprises that also have production capacity in the Greater South East region (and this is especially important for non-manufacturing establishments), if they belong to a multi-region multiplant firm, if they operate in more than one industry (thus gaining from economies of scope), or if they are foreign-owned. However, they are less likely to export if they are a single plant manufacturing enterprise.

All in all, most of the descriptive statistics obtained at the beginning of this chapter equate with prior expectations relating to the importance of such variables and their expected link with exporting. Subsequently, (multivariate) statistical modelling of exporting behaviour is undertaken to test whether these characteristics remain important after accounting for other covariates. The ensuing section presents a model of the determinants of establishment entry into export markets; and conditional on such entry, the proportion of turnover that is sold in overseas markets. The analysis considers the manufacturing and non-manufacturing sectors separately as they have different propensities for internationalisation. The preferred model uses a Heckman sample selection approach, with R&D activity treated as being endogenous (and thus instrument used). The results from estimating the Heckman model are summarised below for manufacturing and non-manufacturing separately.

Manufacturing

With regard to overcoming barriers to exporting, the major results obtained for the manufacturing sector suggest that larger establishments have a much higher probability of selling abroad. From a RBV perspective, presumably size is reminiscent of resource advantages in overcoming the fixed costs of entering international markets. Nevertheless, for those establishments that belong to multi-plant enterprise groups, there is a negative association between the size of the enterprise group and the probability of the establishment's going international, although this relationship is rather weak.

The fact that the establishment engages in R&D activity is associated with a significantly higher likelihood of non-zero exports (although only some 18.6% of UK manufacturing establishments undertook R&D in 2000). As a major innovation of this thesis, a comprehensive empirical measure of absorptive capacity has been derived using factor analysis to extract information from 36 variables covering a wide range of aspects of the knowledge creation/acquisition activities that establishments engage in. As expected, absorptive capacity is found to be important in determining whether an establishment is able to overcome the entry barriers to more competitive global markets. Notably, three types of absorptive capacity play a significant role in this initial process of internationalisation, viz. the absorptive capacity for scientific knowledge, that for international cooperation and lastly that for business organisational structures and practices of human resource management. Other establishment-level characteristics that facilitate export-market entry include higher (labour) productivity and/or higher capital intensity.

On the other side, in terms of factors hampering business innovation, the impact of rigid regulations is found to reduce the likelihood of the establishment exporting. Moreover, from a market/industry perspective, market concentration is linked to a greater probability of exporting. The industry sectors with the highest propensities to export are (*cet. par.*) *textiles*, *chemicals*, *rubber & plastics*, *basic metals*, *machinery & equipment*, *electrical machinery* and *medical & precision instruments*. Lastly, establishments in Northern Ireland are more likely to engage in selling overseas.

Furthermore, the second stage involves estimating the export intensity equation for the UK manufacturing. The determinants of how much to export as a proportion of total turnover are found to be the following. Conditional on having overcome entry barriers into international markets, size continues to be an important determinant of establishment's behaviour in global markets, although this relationship becomes negative. That is, larger establishments tend to export less per unit of their total sales. Moreover, the relationship between export intensity and establishment size is U-shaped.

Contrary to the notable effect on the first stage of internationalisation, undertaking continuous R&D stops playing a role in determining business exporting behaviour post international-market entry, once the endogenous relationship between R&D and exporting activities are taken into account. Nevertheless, absorptive capacity (for absorbing scientific knowledge) still stands out as a significant factor further enhancing the exporting performance of establishments.

The industries with the higher export intensities are *non-metallic minerals*, *motor & transport*, *electrical machinery* and *machinery & equipment*. Lastly, establishments located in London, Wales, Northern Ireland, the South West and Scotland all tend to have significantly higher export intensities.

Non-manufacturing

In terms of the results for who exports in non-manufacturing, similar to the results for manufacturing, the size of the establishment and the industry sector that it belongs to are still two most critical factors behind business decisions to become exporters. The larger the establishments, the more likely they are to start exporting, which is intuitively appealing. The industry sectors with highest export propensities are *wholesale trade*, *computing*, *transport support* and *other business services*. Nevertheless, these effects of size and industries are significantly less important compared to its impact on the likelihood of exporting in the manufacturing sector.

As in the manufacturing sector, if the establishment participates in R&D activity, this is associated with a significantly higher likelihood of non-zero exports, although the impact is smaller, especially when R&D is assumed to be endogenous, and a much smaller proportion of establishments undertake R&D in this sector in the first instance. Nevertheless, in contrast with the manufacturing case, absorptive capacity is not statistically significant in determining the export orientation of establishments in non-manufacturing sector. Additionally, establishments that are part of enterprises that operate in more than one region and/or more than one industry have a higher probability of exporting. As to location effects, establishments in the South West are less likely to engage in selling overseas, while establishments in South East England are more likely to supply overseas markets (overall, again, regional effects are not as strong as those found in manufacturing).

Moreover, establishments with higher labour productivity are more likely to enter export markets, although the effect is not particularly strong. Industry/

market concentration is linked to a smaller probability of exporting, whereas this impact was positive in manufacturing. What's more, the agglomeration degree of the industry is marginally significantly positive in affecting the entry decision.

Turning to the results for non-manufacturing on how much of turnover is exported, the most significant determinants of establishment's exporting performance appear to be size, foreign ownership, product diversification, operation in multiple regions, absorptive capacity, industry effect as well as the effect of locating in London. In particular, it is found that the relationship between export intensity and establishment size in non-manufacturing is strictly negative, with the smallest establishments more likely to export a larger proportion of their turnover when compared to medium- and large-sized companies. Whilst the negative impact of size on export intensity is consistent with the results from manufacturing sector, recall that the strength of this relationship is virtually weaker and non-linear (in particular, U-shaped) in this former sector.

It is worth noting that foreign ownership (especially US) boosts the level of exports per unit of total sales substantially, which presumably could be explained by the nature of such inward foreign direct investments. Meanwhile, the ability to produce diversified product (i.e. to operate in multiple industries, and thus benefit from economies-of-scope) is associated with higher export intensity; whereas having operation in various regions tends to reduce the proportion of overseas sales of companies, as they become more domestically oriented. In addition, absorptive capacity for cooperation at national level seems to further boost establishment's export intensity.

In terms of industry effect, a larger proportions of overseas sales tend to concentrate in the following industries – *transport support*, *computing*, *financial services*, *transport*, with the first two also having higher export propensity. Lastly, the only significant regional effect is identified in establishments located within London, who sell more of their turnover overseas.

Similar to the results obtained for the manufacturing sector, some other establishment-level characteristics that might have been expected to be important (such as labour productivity, R&D activity) are found not to be statistically significant determinants of exporting intensity in non-manufacturing.

3.3 Determinants of Innovating Activities

As reviewed in the previous chapter (pp.41-59), the key variables that are frequently documented to determine the firm's R&D spending include the firm-specific characteristics, such as size, absorptive capacity, productivity, capital intensity, ownership, where there exist barriers to innovation; industry/market factors, such as technological opportunity and/or appropriability, knowledge spillovers; government policy instruments, so on and so forth. This section empirically tests the deciding factors of the establishment's R&D behaviour, using the same data source as what has been employed in modelling exporting activities (i.e. the matched *CIS3-ARD* dataset), to ensure consistency and allow synthesis of micro exporting and R&D behaviour at the end of this chapter.

3.3.1 R&D Doers vs. Non-R&D Doers: Some Basic Characteristics

As before, this part presents some basic comparisons between those undertaking R&D and those not doing so, as well as some establishment-level characteristics before discussing multivariate modelling results in the following section.

In terms of the percentage of establishments undertaking such spending in 2000, the UK figure for manufacturing was 18.6% and 9.7% for services. In terms of the amount spent on R&D per employee (for those establishments engaged in this activity), the UK figure was around £2,900 per employee for manufacturing and £2,000 per employee for services.

Using the variables in Table 3-1, their average values are compared in Table 3-11, sub-divided into those establishments that undertake R&D and those that do not, for manufacturing and non-manufacturing sectors respectively (given the known differences in the propensity to conduct R&D between these sectors).

Table 3-11: Mean values of certain characteristics of UK establishments that undertook R&D or not, 2000

Variables	Manufacturing			Non-manufacturing		
Undertaking R&D =	yes	no	total	yes	no	total
Absorptive capacity (external knowledge)	0.86	-0.02	0.14	0.72	-0.18	-0.09
Absorptive capacity (national co-op)	0.45	-0.06	0.03	0.30	-0.07	-0.03
Absorptive capacity (org structure & HRM)	0.48	-0.05	0.05	0.54	-0.09	-0.03
Absorptive capacity (international co-op)	0.43	-0.02	0.06	0.12	-0.07	-0.05
Absorptive capacity (scientific knowledge)	0.09	-0.02	0.00	-0.05	-0.01	-0.02
Export*	0.73	0.38	0.44	0.34	0.14	0.16
Labour productivity (£'000 turnover per worker)	97.18	140.99	132.87	185.72	472.83	445.03
Capital/labour ratio	8.73	6.48	6.90	5.24	3.86	4.02
Age (years)	7.35	6.47	6.63	3.32	2.72	2.79
Herfindahl index	0.09	0.08	0.08	0.11	0.09	0.10
Industry agglomeration	1.92	1.61	1.67	0.89	0.77	0.78
Diversification	0.58	0.59	0.59	0.60	0.59	0.59
ln Density ('000 per hectare)	1.92	2.01	1.99	2.29	2.06	2.08
Single plant*	0.75	0.82	0.81	0.79	0.79	0.79
>1 SIC multiplant*	0.34	0.22	0.25	0.18	0.15	0.15
>1 region multiplant*	0.15	0.08	0.10	0.10	0.08	0.09
SE*	0.06	0.04	0.04	0.04	0.03	0.03
Received public support*	0.24	0.07	0.10	0.17	0.04	0.05
Excessive perceived economic risks *	0.19	0.19	0.19	0.15	0.11	0.11
High costs of innovation*	0.24	0.25	0.25	0.25	0.16	0.17
Cost of finance	0.18	0.21	0.20	0.20	0.14	0.15
Organisational rigidities within the enterprise*	0.09	0.07	0.07	0.06	0.05	0.05
Lack of qualified personnel*	0.13	0.13	0.13	0.15	0.10	0.10
Lack of information on technology*	0.04	0.06	0.06	0.03	0.04	0.04
Lack of information on markets*	0.09	0.07	0.07	0.06	0.05	0.05
Impact of regulations/standards*	0.20	0.16	0.16	0.21	0.13	0.14
Lack of customer responsiveness*	0.12	0.12	0.12	0.14	0.09	0.09
Foreign-owned*	0.04	0.02	0.02	0.01	0.01	0.01

See Table 3-1 for definitions. * denotes a dichotomous variable.
Source: weighted *CIS3-ARD*

The important findings following such mean comparisons are highlighted below:

- absorptive capacity is significantly higher in those establishments that conduct R&D (particularly that capacity for appropriating external knowledge, and especially in the manufacturing sector);
- establishments that export are much more likely to engage in R&D activity (and again this association between R&D and export is more pronounced in manufacturing sector);
- establishments undertaking R&D tend to be older, with higher capital intensity;
- R&D doers are more likely to belong to more concentrated industries and more agglomerated economies;
- establishments are more likely to be innovative if they belong to enterprises that also have production capacity in the Greater South East region; if they belong to a multi-region firm, operate in more than one industry (thus gaining from economies of scope) and/or are foreign-owned (at least for manufacturing sector);
- establishments (particularly in the manufacturing sector) that undertake R&D are more likely to receive support from the public sector;
- finally and rather unexpectedly, various factors that are reported as being barriers to innovation do not seem to play an important role in distinguishing R&D doers from others. Nevertheless, these (univariate) associations do not take account of covariates, and thus call for the (multivariate) statistical modelling to test whether these barrier variables have any role to play in hampering innovative activities.

Table 3-12: R&D proportion and intensity in UK establishments, 2000, by industry

Industry (1992 2-digit SIC)	proportion of R&D doers, %	R&D intensity, %
Manufacturing		
Mining & quarrying (10-14)	10	0.45
Food & drink (15)	14	1.08
Textiles (17)	15	1.08
Clothing & leather (18)	6	0.88
Wood products (20)	12	0.45
Paper (21)	21	0.53
Publishing & printing (22)	9	518.85
Chemicals (23-24)	36	8.64
Rubber & plastics (25)	25	1.58
Non-metallic minerals (26)	12	1.53
Basic metals (27)	22	4.73
Fabricated metals (28)	12	0.98
Machinery & equipment n.e.s. (29)	31	2.91
Electrical machinery (20-32)	32	12.76
Medical etc instruments (33)	26	230.06
Motor & transport (34-35)	20	2.10
Furniture & manufacturing n.e.s. (36)	17	249.11
Non-manufacturing	0	
Construction (45)	5	0.85
Wholesale trade (51)	9	5.44
Transport (60-62)	5	3.73
Transport support (63)	4	0.81
Post & telecom (64)	16	47.41
Financial (65-67)	15	8.81
Real estate (70)	7	13.97
Machine rentals (71)	9	2.83
Computing (72)	32	47.30
Other business (74)	13	5.20
All sectors	13	35.62

Notes: figures are percentages.
Source: weighted data from *CIS3-ARD*. n.e.s. denotes 'not elsewhere specified'.

Table 3-12 provides cross-industry comparison of the proportions of R&D undertakers and R&D intensities. On balance, both the percentage of establishments undertaking R&D and the R&D-sales ratio are higher in manufacturing sector. In particular, R&D activity is much more prevalent in certain manufacturing sectors such as *chemicals* (36%), *electrical machinery* (32%), *machinery & equipment n.e.s.* (31%), *medical instruments* (26%), *Rubber & plastics* (25%). On the other side, R&D intensity is very high in certain industries such as *publishing & printing*, *furniture & manufacturing n.e.s.*, *medical etc instruments* and *electrical machinery*, etc.

Table 3-13: R&D proportion and intensity in UK establishments, 2000, by GO region

Region	Manufacturing		Non-manufacturing	
	proportion of R&D doers, %	R&D intensity, %	proportion of R&D doers, %	R&D intensity, %
East Midlands	19	2.19	7	4.10
Eastern	22	7.81	10	14.35
London	13	2.10	12	33.43
North East	24	524.66	5	1.28
North West	16	6.91	8	2.68
Northern Ireland	14	2.80	7	5.39
South East	21	3.41	11	7.92
South West	21	98.66	8	5.59
Scotland	17	8.46	11	2.93
West Midlands	17	1.20	12	7.16
Wales	20	4.19	6	2.89
Yorks-Humberside	17	28.20	10	11.60
All	19	56.94	10	11.96

Notes: figures are percentages.
Source: weighted data from *CIS3-ARD*.

Table 3-13 presents data on R&D activity by Government Office region. In terms of the manufacturing sector, the North East and Eastern England have the highest percentages of establishments that undertake R&D, i.e. 24% and 22% respectively; while the North East also enjoys the highest intensity of conducting R&D, followed by the South West. In contrast, London has the smallest proportion of its establishments engaged in R&D activity (13%) and a much lower level of R&D intensity. When non-manufacturing is considered, regional rankings are very different (almost the reverse) with London and West Midlands having the highest percentage of establishments that do R&D (i.e. 12%) and London with the highest R&D intensity, while the North East has the lowest proportion with only 5% of non-manufacturing establishments engaged in exporting, as well as the lowest R&D intensity. Again as in the case of exporting activities, this sharp contrast may be explained by the higher concentration of non-manufacturing businesses in London.

Table 3-14: Distribution of establishments, 2000, by whether exported and/or undertook R&D

	Do not export (% of Total)	Export (% of Total)	Total
Manufacturing			
No R&D	1492 (62)	904(38)	2396
Undertake R&D	149(27)	397(73)	546
All	1641(56)	1301(44)	2942
Non-manufacturing			
No R&D	3935(86)	661(14)	4596
Undertake R&D	338(65)	186(35)	524
All	4273(83)	847(17)	5120

Source: weighted data from *CIS3-ARD.*

In terms of the exporting and innovating activities being undertaken, Table 3-14 shows that in manufacturing some 44% of establishments were involved in exporting, while only less than 19% incurred spending on R&D in 2000. The table also shows that some 31% of exporters also engaged in R&D activity (or alternatively, nearly 73% of those manufacturing establishments undertaking R&D also exported). This suggests a strong relationship between the two activities, although there were a substantial number of establishments that exported but without finding it necessary to also engage in R&D.

Table 3-15: R&D proportion and intensity in UK establishments, 2000, by size

Employment size	Manufacturing		Non-manufacturing		Total	
	proportion of R&D doers, %	R&D intensity, %	proportion of R&D doers, %	R&D intensity, %	proportion of R&D doers, %	R&D intensity, %
0-9	6	14.27	4	19.18	5	17.75
10-49	15	110.26	10	13.73	12	57.94
50-249	27	1.75	13	6.57	20	3.40
250+	39	2.47	22	2.14	32	2.36
Total	19	56.94	10	11.96	13	35.62

Notes: figures are percentages.
Source: weighted data from *CIS3-ARD*.

Table 3-15 shows that the proportion of R&D active establishments increases with establishment size (especially in the manufacturing sector with almost 40%

of businesses employing 250 or more workers engaged in R&D). Nevertheless, the relationship between size and R&D intensity does not appear to be linear; R&D-sales ratio seems to reach its peak in medium-sized establishments (i.e. those with 10-49 employees), which then starts to decrease significantly in the two largest size groups (i.e. those employing 50-249 and 250+ workers). This non-linearity in the size-R&D relationship will be formally tested in subsequent econometric modelling in the following section.

In a nutshell, most of these descriptive statistics discussed here are consistent with prior expectations relating to the importance of such variables and their expected link with innovative activities. However, these (univariate) associations between R&D and various establishment characteristics do not take account of covariates (such as the size of the establishment or industry), and therefore the next section investigates further in a multivariate statistical setting to test whether these characteristics remain important in the econometric modelling of the determinants of R&D activity.

3.3.2 An Empirical Investigation

In modelling the determinants of exporting in the earlier part of this chapter, R&D features as a right-hand-side explanatory variable of the establishment's exporting behaviour. As reviewed at the end of Chapter 2 (pp.59-69), the early consensus in the literature points to the causality running from undertaking innovation activities to internationalisation. In essence, product differentiation (induced by undertaking R&D activity) is expected to translate into competitive advantages that allow exporting firms to compete in foreign markets. This theory on innovation-led exports has been empirically tested and supported by the evidence documented in the first part of this chapter.

On the other side, it is equally reasonable to expect that the direction of this causality between innovative and exporting activities may go from the latter to the former, given the theoretical predictions of macroeconomic models on endogenous technology/innovation and growth (*c.f.* Romer, 1990; Aghion and Howitt, 1998). From a micro perspective, the fact that exporters are exposed to a richer source of technology in global markets is likely to be associated with increased competency-base (for innovative activities) at home. Thus, there could also be some 'learning-by-exporting' effect in terms of technological enhancement within the exporting firms[56].

Given the earlier finding in this chapter that R&D is a significant determinant of the establishment's decision to internationalise (pp.89-105), this R&D-exporting relationship is likely to be endogenous. Indeed, firms may be motivated to undertake R&D because of their anticipated involvement in overseas markets. In other words, in order to break down the barriers to internationalisation, firms must improve their performance prior to exporting (including technological performance). Again as with the case of exporting modelling, this endogenous link between R&D and exporting is controlled for by using the Heckman approach. Nevertheless, given the cross-sectional nature of the data, it is worth noting that the causality issues between exporting and R&D activities can not be adequately addressed here using econometric modelling.

Therefore, as with the modelling of exporting, similar two-stage Heckman models are estimated here based on the same data source, i.e. the matched *CIS3-ARD* dataset, but with whether the establishment undertakes R&D (or not) and R&D intensity as the left-hand-side variables. In choosing the likely determinants of whether R&D spending takes place or not, the models estimated here have included those variables that have been shown to be important in the literature (*c.f.* those reviewed in Chapter 2) and are available in the *CIS3-ARD* dataset. Thus, the variables incorporated into the two-stage Heckman model cover most variables presented in Table 3-1, including establishment size (to proxy for scale advantages), absorptive capacity indices (for the ability to internalise and appropriate knowledge), industry/market characteristics (for technological opportunity, any agglomeration and/or diversification effects), ownership features (such as whether a single-plant enterprise or part of a larger enterprise and country of ownership), location (in terms of standard UK Government Office regions), R&D spillovers, whether a recipient of support from public sector with innovation activities, information on the factors that hamper innovation and so forth.

[56] Note this learning effect in terms of innovative capacity is discussed in a different context to that associated with productivity gains, which will be addressed in Chapters 4 and 5.

In particular, a variable has been derived to measure potential R&D spillovers. This is obtained as the sum of R&D spending of all other establishments in the 2-digit SIC industry in which the establishment is located (i.e. excluding the R&D spending of the establishment itself). The expectation here is that the greater the spending by other firms that are technologically linked (through membership of the same industry), the greater the potential for spillovers of non-appropriable knowledge and information to establishments belonging to that industry[57].

Manufacturing

The results for the manufacturing sector are presented in Table 3-16 and Table 3-17, based on the Heckman sample selectivity approach. The results relating to whether R&D is undertaken or not are provided in Table 3-16, with marginal effects reported (i.e. the *ceteris paribus* change in the probability of an establishment undertaking R&D with respect to a change in each determinant). Note, as with the model for exporting, a stepwise regression procedure is adopted with variables retained in the model that has associated parameter estimates significant at the 10% or better level.

[57] Ideally, the R&D spending by other firms should be weighted here to provide a more accurate picture of intra- and inter-industry R&D linkages. Nevertheless, such information is not available in CIS3 data.

Table 3-16: Determinants of R&D spending in UK manufacturing, 2000

Dependent variable: R&D undertaken or not	Model 1		Model 2		Means
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	($\bar{x}$)
Export	0.089	6.03	–	–	0.440
Establishment size					
10-19 employees	0.081	1.96	0.090	2.10	0.268
20-49 employees	0.084	2.25	0.109	2.74	0.353
50-199 employees	0.094	2.15	0.137	2.87	0.214
200+ employees	0.100	2.03	0.155	2.78	0.075
Absorptive capacity					
Absorptive capacity (external knowledge)	0.109	14.23	0.117	15.08	0.132
Absorptive capacity (national co-op)	0.032	7.13	0.034	7.33	0.029
Absorptive capacity (org structure & HRM)	0.040	6.88	0.044	7.45	0.053
Absorptive capacity (international co-op)	0.017	3.79	0.020	4.25	0.051
Factors hampering innovation					
High cost of innovation	-0.031	-2.28	-0.035	-2.55	0.254
Lack of customer responsiveness	-0.028	-1.75	-0.033	-2.01	0.121
Other factors					
Received public sector support	0.081	3.24	0.087	3.38	0.103
Industry sector (2-digit 1992 SIC)					
Chemicals	0.066	1.67	0.101	2.22	0.042
Rubber & plastics	0.093	2.47	0.114	2.97	0.063
Machinery & equipment nes	0.096	3.22	0.118	3.78	0.100
Electrical machinery	0.095	3.46	0.125	4.17	0.070
Furniture & manufacturing nes	0.045	1.68	0.048	1.81	0.067
Region					
Eastern England	0.043	1.66	0.047	1.80	0.085
ρ	-0.182	-1.77	-0.173	-1.61	
σ	1.256	30.15	1.255	29.49	
λ	-0.228	-1.73	-0.217	-1.57	
(unweighted) N	3419		3419		
N (R&D > 0)	750		750		
Log pseudo-likelihood	-1836.485		-1858.879		
Wald test of independent equations: $\chi^2(1)$	2.99		2.49		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of ‘export’ (hence the predicted value is used based on the reduced-form model in Table 3-24). Marginal effects are reported; for a binary variable, this refers to the discrete change of this variable from 0 to 1. The reported parameter estimates are all statistically significant at the 10% level. Weighted regression is used with merged *CIS-ARD* data. For variable definitions, see Table 3-1.

Being an exporter seems to increase the probability of also undertaking R&D by almost 9%; nevertheless, once the endogenous nature of exporting has been taken into account (i.e. in Model 2), the results obtained here fail to suggest any significant ‘learning-by-exporting’ effect in terms of intensifying R&D behaviour. There could be a number of explanations for the lack of impact of exporting on R&D behaviour. First of all, this innovative advantage conferred by exporting could be better embodied in the productivity gains (as will become evident in Chapter 5); and thus this learning effect induced by participation in international markets is often not directly measured but considered indirectly through the link between innovation and productivity growth. Secondly and most importantly, the exporting variable (defined as whether an establishment had non-zero export sales) only captures the average effect of exports on R&D behaviour; however, given only some 26% of all establishments exported achieving an average less than 7% export volume per unit of total sales in 2000, this effect may not be very pronounced.

In *CIS3* questionnaire, establishments are asked to identify their largest market, be it local, regional, national or international. Thus if the establishment's largest market is identified as overseas, this could be taken as an indication of strong export orientation. Therefore, some alternative models have been estimated to test whether a stronger measure of exporting might have an impact on R&D activity. Table 3-26 (in the Appendix to this chapter) provides an alternative estimation to that presented in Table 3-16, using 'largest market international' as a RHS variable (instead of simply 'export or not') in a similar model of R&D behaviour. The results in Table 3-26 show that when such a variable is treated as exogenous, establishments mainly serving export markets are almost 16% more likely to spend on R&D; whereas when its endogeneity is controlled for, such impact of strong export orientation drops to around one-third the effect (with exporting-dominated establishments being some 5% more likely to undertake R&D).

The size of the establishment seems to have a major positive impact on the likelihood of R&D expenditure taking place: vis-à-vis the baseline group (i.e. establishments employing less than 10 people), moving to the 10-19 employment band increases the probability of doing R&D by 9%; employing 20-49 workers raises the probability by some 11%, and up to an increase of nearly 14% for establishments with 50-199 employees and almost 16% in those in the 200+ size band.

Absorptive capacity is also found to be important in determining whether an establishment engages in R&D spending, with the following four types being important drivers: the absorptive capacity for external knowledge, that for organisational structure and human resource management, and that for cooperation at both national and international levels. Amongst these, the absorptive capacity for external knowledge appears to be most significant in determining R&D. This is unsurprising, given the notion of complementarity between in-house R&D and R&D acquired externally (see p.14 for a review of literature on such complementarity), which is also consistent with Cohen and Levinthal (1990)'s original elaboration of absorptive capacity – the ability to identify and utilise the outside knowledge as a critical component of a firm's capabilities. Therefore absorptive capacity plays a major role in explaining why relatively few establishments undertake any R&D in the UK.

As to factors that are quoted to have a high importance in hampering businesses' ability to innovate, the high costs of innovation and lack of customer responsiveness to new goods and services both have reduced the probability of undertaking R&D. However, having controlled for other covariates, the impact of these innovation barriers is generally not large despite the fact that between 20-25% of establishments state that costs are a significant barrier to innovation. On the positive side, establishments that have received public sector support are nearly 9% more likely to spend on R&D compared to those not receiving such assistance.

Sector also matters – with all those industries listed having higher propensities to undertake R&D (by between 5 to 13%) vis-à-vis all other manufacturing sectors not explicitly listed. For instance, those industries with higher export propensity include *electrical machinery*, *machinery & equipment n.e.s.*, *rubber & plastics*, etc. Meanwhile, in terms of regional disparity, establishments located in Easter England are found to be more likely to invest in R&D. Nevertheless, the results imply no significant effect of intra-industry spillovers of R&D activity.

Turning to the second stage of modelling the business's R&D behaviour, in terms of what determines the level of R&D spending per unit of sales, a similar set of variables are used as in the first-stage model determining whether any R&D takes place. Additionally, information has been included to capture the complementarity of R&D activity (*c.f.* Cassiman and Veugelers, 1999). More specifically, establishments have the option to choose various approaches to undertaking R&D, akin to 'make' and/or 'buy' decisions. Put differently, they can choose to undertake R&D themselves and develop their own technology (i.e. intramural R&D) and/or source externally (i.e. extramural R&D and/or licence know-how). To acquire a technology they can also choose to cooperate in joint R&D activity with other businesses. Hence, establishments in the *CIS3* dataset have been classified into those that undertake ‘make’, ‘buy’ or ‘cooperate’ decisions (or any combination of these three options)[58].

[58] The ‘make’ sub-group engage in intramural R&D spending; the ‘buy’ sub-group acquire either external R&D and/or other external knowledge. The ‘cooperation’ sub-group comprise those that have co-operative arrangements on innovation activities with another (i.e. not their own) enterprise or institution.

Table 3-17: Determinants of R&D intensity in UK manufacturing, 2000 (cont.)

Dependent variable: *ln* R&D intensity	Model 1		Model 2		Means ($\bar{x}$)
	$\hat{\beta}$	*z*-value	$\hat{\beta}$	*z*-value	
Complementarity of R&D activities					
R&D make only	0.754	5.31	0.761	5.36	0.310
R&D make & buy	1.485	9.37	1.487	9.32	0.206
R&D make & cooperate	0.566	2.30	0.572	2.31	0.064
R&D make, buy & cooperate	1.605	8.57	1.609	8.49	0.066
Establishment size					
20-49 employees	-0.399	-2.40	-0.403	-2.42	0.340
50-199 employees	-0.731	-4.09	-0.737	-4.15	0.308
200+ employees	-1.178	-5.61	-1.179	-5.62	0.151
ln enterprise size x Multi-plant	0.108	2.89	0.107	2.88	1.327
Absorptive capacity					
Absorptive capacity (scientific knowledge)	0.084	3.19	0.084	3.20	0.065
Factors hampering innovation					
High cost of innovation	-0.245	-2.02	-0.247	-2.04	0.238
Other factors					
ln Age	-0.162	-2.75	-0.165	-2.81	1.208
ln Labour productivity (£'000 per worker)	-0.881	-7.45	-0.875	-7.46	4.188
ln Capital/employment ratio (£m per worker)	0.247	3.69	0.250	3.75	-5.410
Multi-plant enterprise > 1 region	-0.419	-1.76	-0.419	-1.76	0.150
Received public sector support	0.305	2.29	0.306	2.28	0.240
Industry sector (2-digit 1992 SIC)					
Clothing & leather	1.040	2.69	1.048	2.66	0.012
Publishing & printing	0.606	2.44	0.599	2.42	0.050
Chemicals	1.212	4.59	1.207	4.50	0.073
Rubber & plastics	0.622	2.91	0.619	2.87	0.090
Basic metals	0.697	2.58	0.697	2.57	0.032
Fabricated metals	0.528	2.66	0.533	2.68	0.124
Machinery & equipment nes	0.852	3.68	0.853	3.68	0.172
Electrical machinery	1.314	6.39	1.312	6.28	0.124
Medical etc instruments	2.013	8.50	2.023	8.59	0.047
Motor & transport	1.350	6.00	1.347	6.00	0.040
Furniture & manufacturing nes	1.034	4.51	1.034	4.50	0.060
Region					
North West	-0.385	-1.96	-0.378	-1.94	0.091
Scotland	0.411	1.96	0.413	1.97	0.084

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of 'export' (hence the predicted value is used). All parameter estimates are statistically significant at least at the 10% level. Weighted regression is used with merged *CIS-ARD* data. Values of diagnostic tests are the same as in Table 3-16. For variable definitions, see Table 3-1.

Table 3-17 reports the results for manufacturing with respect to how much R&D takes place per unit of sales, for those with positive R&D spending (thus these results cover only 750 establishments from a total of 3474 included in the analysis). Those manufacturing establishments that do R&D are not a random sample of the population of all establishments; in fact, those that do R&D, such that positive R&D spending is observed, overcome barriers to undertaking R&D that are measured from the first stage (i.e. probit) of the Heckman model.

As with the case of the first-stage model determining R&D probability, exporting is again found to have no role in influencing how much establishments spend on R&D activity. Nevertheless, following the alternative model experimented earlier (p. 121) where strong export-orientation is used (instead of simply 'export or not'), as reported in Table 3-27 (in the Appendix), establishments with overseas sales as their main market spend on average (*cet. par.*) around 206%[59] more on R&D per unit of sales; when such strong exporting is treated as endogenous, its effect on R&D intensity declines marginally to around 183%.

Perhaps not surprisingly, Table 3-17 shows that establishments that engage in R&D 'make' (i.e. incur intramural R&D expenditure) have significantly higher levels of R&D spending per unit of total sales, vis-à-vis the baseline group (the 'R&D buy-in only' sub-group − those who only 'buy-in' R&D); this applies to those that invest in R&D 'make' only as well as those with both intramural and extramural R&D expenditure (in terms of 'buy-in' and/or 'co-operate').

In particular, those engaged in 'make', 'buy-in' and cooperating with others in joint R&D projects have (*cet. par.*) the highest levels of R&D intensity – they spend almost 400% more on R&D per unit of sales in relation to those that only 'buy-in' external R&D. Moreover, the group with the second highest intensity are those involved in intramural spending and 'buying-in' – some 340% higher compared with the same benchmark group. Lastly, the R&D spending per unit of sales is 114% higher in those that invest in intramural R&D only and 77% higher in those that both invest in in-house R&D and co-operate in R&D activity (vis-à-vis those that only 'buy-in' R&D). Thus, R&D intensity is significantly higher when the establishment engages in intramural spending; and combining this with other forms of (extramural) R&D spending is associated with even higher levels of R&D, implying that different forms of R&D activities are virtually complementary as long as the establishment itself is able to conduct innovative activities in house. When R&D is solely acquired externally and thus fails to include any direct spending within the establishment, such activities tend to be substitutes and hinder overall spending on R&D per unit of sales (and thus the establishment's innovative capacity). The mean values of the variables (as shown in the last

59 Since the dependent variable in the model is the natural log of R&D intensity, the elasticity with respect to a dichotomous variable is given by $\exp(\hat{\beta})-1$.

column) show that overall, more than 64% of establishments in the UK manufacturing undertake in-house R&D and almost 34% are engaged in complementary activities involving intramural spending which boosts R&D intensity, despite the fact that still a large proportion of these establishments are engaged in only ‘buying-in’ R&D (although not shown in the table).

While Table 3-16 shows that the size of the establishment have a major impact on whether R&D expenditure takes place or not (the larger the establishment, the greater the probability of undertaking R&D, reflecting the availability of necessary resources to overcome the fixed costs of R&D activity), Table 3-17 shows that conditional on having overcome such ‘entry barriers’, larger plants spend less on R&D per unit of sales. Particularly, those in the largest size band (i.e. employing 200+ workers) spend 69% less on R&D activity in relation to those smallest establishments (with less than 10 employees). The literature on the relationship between R&D spending and the size of the firm (as discussed in Chapter 2, pp.41-44) suggests that most previous work in this area finds a positive link between size and overcoming entry barriers into R&D, but there are also reasons for a negative relationship between size and R&D intensity (conditional on participation in R&D activity). For instance, intensive R&D may be used more as a means of breaking down barriers to entry into certain product markets when businesses are small. As they grow larger and presumably more productive, due to scale/scope economies, less resources may be required to invest in R&D for each unit of output produced. Moreover, R&D conducted in larger firms may be more productive (hence less per unit of sales is needed) and that the nature of R&D in larger firms may be more process (than product) oriented and therefore requires lower levels of relative spending.

Therefore, a future avenue to pursue in the follow-up research is to examine the establishment’s investment in product/process innovation, and test whether this size effect becomes positive in the context of process innovation.

Table 3-18 illustrates that R&D intensity is significantly higher for the smallest establishments that introduce product innovations, while intensity is much lower for both larger establishments with product innovations and establishments of any size with process innovations. This table also shows that larger establishments with process innovations have lower R&D intensities vis-à-vis the smallest establishments, suggesting some efficiency gains from size, but the differential is relatively small when compared to the relationship between R&D intensity and size for product innovators.

Table 3-18: R&D intensity in UK manufacturing by type of innovation produced

Size \ Innovation type	Non innovators		Product innovators		Process innovators		Product & process innovators	
1-49	4.44	(15.9)	229.09	(16.8)	8.65	(5.5)	109.28	(15.0)
50-199	1.08	(8.7)	3.03	(8.6)	1.02	(3.4)	1.76	(10.8)
200+	2.07	(3.4)	2.72	(3.7)	0.70	(1.8)	2.30	(6.3)

Notes: R&D intensity is defined as:100×(amount spent on R&D÷turnover). Note only establishments with R&D > 0 included. Figures in parenthesis are percentage of all manufacturing establishments. Source: weighted *CIS3* data.

However, contrary to this establishment-level size effect, those establishments that belong to multi-plant firms tend to experience a positive impact of business size on their R&D spending. Table 3-16 also suggests that absorptive capacity (especially that for external knowledge) is highly important in determining whether an establishment engages in R&D spending. The absorptive capacity for utilising scientific knowledge is also important in determining how much is spent on R&D per unit of sales, but absorptive capacity on balance, has a much smaller relative effect on this intensity, compared to its role in overcoming barriers to undertaking R&D[60].

Perhaps not consistent with the priori expectation, age of the establishment and its labour productivity are both associated with lower R&D intensity. That is a £1000 increase in turnover per employee in the establishment reduces (*cet. par.*) its R&D intensity by 0.875; as the establishment grows one year older, its R&D intensity also decrease (*cet. par.*) by 0.165. In addition, if the establishment belongs to an enterprise that has plants in various regions, this lowers its R&D intensity by 34%, holding other factors constant. One possible explanation is that these adverse impacts of age, labour productivity and being owned by multi-region enterprise on the establishment's R&D spending per unit of sales, might simply be mirroring the negative size effect (as size is usually

[60] Note, in the semi-log model (with the dependent variable logged), the elasticity (at the mean) of a continuous variable (like any index of absorptive capacity) is given by $\overline{X}\hat{\beta}$.

found to be positively associated with age and productivity), for the reasons as discussed above.

On the other side, having higher capital intensity helps boost spending in R&D per unit of sales. In addition, establishments that have received public sector support spent (*cet. par.*) almost 36% more on R&D per unit of sales compared to those not receiving such assistance. The proportion of establishments undertaking R&D and also receiving support is about a quarter of the total, suggesting that without such differential levels of support, R&D intensity might have been significantly lower.

As with the determinants of whether R&D is undertaken or not, sector also matters in explaining R&D intensity, with all those industries listed having higher R&D intensities (by between 70 to 656%) vis-à-vis all other manufacturing sectors not explicitly listed. The industries with highest R&D intensities include *medical instruments*, *motor and transport*, *electrical machinery*, *chemicals* and so on. In terms of location effect, those establishments located in Scotland seem to have the highest R&D intensity while those situated in the North West appear to have the lowest intensity.

As to factors that establishments listed as having a high importance in hampering their ability to innovate, only the direct cost of innovation being too high seems to hinder businesses' R&D spending. Given that a relatively large proportion of establishments (i.e. some 24%) rate this factor as being highly noticeable, and this tends to reduce (*cet. par.*) R&D intensity by nearly 22%, high innovation cost is indeed a significant barrier to business R&D activity.

Non-manufacturing

Turning now to the non-manufacturing results, Table 3-19 presents the results for estimating the first-stage of the Heckman model regarding whether R&D is undertaken or not. As usual, the interpretation here is based on the results obtained from estimating Model 2, where the endogenous relationship between R&D and exporting is controlled for by using instrumented exports variable.

Table 3-19: Determinants of R&D spending in UK non-manufacturing, 2000

Dependent variable: R&D undertaken or not	Model 1		Model 2		Means
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	$(\bar{x})$
Export	0.059	4.91	–	–	0.164
Establishment size					
10-19 employees	0.027	1.89	0.029	1.96	0.346
20-49 employees	0.028	1.88	0.036	2.34	0.322
50-199 employees	0.024	1.42	0.034	1.82	0.137
200+ employees	0.063	2.43	0.084	2.85	0.031
Absorptive capacity					
Absorptive capacity (external knowledge)	0.055	12.85	0.058	13.31	-0.088
Absorptive capacity (national co-op)	0.014	4.22	0.014	4.29	-0.032
Absorptive capacity (org structure & HRM)	0.022	7.07	0.024	7.26	-0.048
Absorptive capacity (international co-op)	0.013	3.40	0.014	3.79	-0.050
Other factors					
Received public sector support	0.045	2.55	0.048	2.53	0.052
Industry sector (2-digit 1992 SIC)					
Financial services	0.197	1.08	–	–	0.001
Computing	0.145	4.14	0.162	4.48	0.042
Other business services	0.039	3.81	0.042	3.89	0.243
ρ	-0.655	-7.80	-0.632	-7.25	
σ	1.625	13.43	1.614	12.89	
λ	-1.064	-5.21	-1.020	-4.86	
(unweighted) N	4016		4016		
N (R&D > 0)	427		427		
Log pseudo-likelihood	-1887.352		-1913.514		
Wald test of independent equations: $\chi^2(1)$	28.40		26.34		

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of 'export' (hence the predicted value is used based on the reduced-form model in Table 3-25). Marginal effects are reported; for a binary variable, this refers to the discrete change of this variable from 0 to 1. The reported parameter estimates are all statistically significant at the 10% level. Weighted regression is used with merged *CIS-ARD* data. For variable definitions, see Table 3-1.

The reported marginal effects suggest a similar picture to the case of manufacturing, although the impact of each variable is far less pronounced. To start with, similar to the case with manufacturing, although export variable appears to be marginally significant in Model 1, after controlling for the endogeneity in its relationship with R&D spending in Model 2, it no longer has a statistically significant impact on business's R&D decision – whether an establishment exports or not, on average, does not have a (*cet. par.*) impact on its R&D behaviour in the non-manufacturing sector. Nevertheless, again in the alternative model of R&D, when the exporting measure is replaced with strong export orientation (see Table 3-28 in the Appendix), if an establishment is mainly serving international markets, it is around 4% more likely to spend on R&D, after controlling for the endogeneity.

Establishment size continues to have a deciding role on whether R&D activity are undertaken, although this effect is more limited to boost the probability by between 3% (as in establishments employing 10-19 staff) and just more than 8% (as in the largest establishments with 200+ employees), in relation to the benchmark group (i.e. those employing less than 10 people).

Absorptive capacity is again found to be important in determining whether an establishment engages in R&D spending, with the same following four types exerting a positive impact on establishment's tendency to invest in R&D: the absorptive capacity for external knowledge, that for organisational structure and human resource management, and that for cooperation at both national and international levels. Once gain, the absorptive capacity for external knowledge stands out as the most significant in determining R&D.

None of the barriers-to-innovation variables turn out to be statistically significant, indicating these quoted reasons (e.g. cost of finance, lack of information on markets, etc.) are not the factors hindering the establishment's ability to conduct R&D activity. On the other side, vis-à-vis establishments not in recipient of any public sector support, establishments that have received such assistance are some 5% more likely to spend on R&D.

There also appears to be some limited sectoral effect. In particular, the establishments that belong to *computing* and *other business services* sectors are roughly 16% and 4% more likely to have non-zero R&D expenditure. However, there is not statistically significant regional effect identified.

The results from estimating the second stage of R&D intensity for non-manufacturing establishments are presented in Table 3-20. These results are, in general, broadly similar to those obtained for the manufacturing.

Table 3-20: Determinants of R&D intensity in UK non-manufacturing, 2000 (cont.)

Dependent variable: *ln* R&D intensity	Model 1		Model 2		Means
	$\hat{\beta}$	*z*-value	$\hat{\beta}$	*z*-value	($\bar{x}$)
Complementarity of R&D activities					
R&D make only	0.954	4.61	1.027	4.88	0.172
R&D make & buy	1.679	7.07	1.768	7.40	0.130
R&D make, buy & cooperate	1.259	4.12	1.290	4.16	0.036
Establishment size					
20-49 employees	-0.555	-2.65	-0.571	-2.77	0.356
50-199 employees	-0.454	-2.01	-0.490	-2.15	0.189
200+ employees	-1.648	-3.97	-1.665	-3.89	0.070
ln enterprise size x Multi-plant	-0.137	-3.69	-0.139	-3.60	0.946
Absorptive capacity					
Absorptive capacity (external knowledge)	-0.461	-3.37	-0.457	-3.33	0.725
Absorptive capacity (national co-op)	-0.117	-2.66	-0.113	-2.56	0.316
Absorptive capacity (international co-op)	-0.108	-2.50	-0.110	-2.53	0.134
Absorptive capacity (scientific knowledge)	-0.070	-2.95	-0.064	-2.33	-0.023
Factors hampering innovation					
Lack of customer responsiveness	0.428	1.96	0.439	1.98	0.153
Other factors					
ln Labour productivity (£'000 per worker)	-0.843	-10.21	-0.808	-10.03	4.197
Industry agglomeration	0.084	1.69	0.093	1.73	0.902
Operated in > 1 SIC	0.553	2.22	0.592	2.35	0.185
US-owned	2.480	3.25	2.429	3.31	0.007
Industry sector (2-digit 1992 SIC)					
Construction	-0.798	-4.40	-0.858	-4.70	0.131
Transport	-0.632	-2.14	-0.716	-2.49	0.041
Region					
North East	-0.855	-1.91	-0.902	-2.30	0.025

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of ‘export’ (hence the predicted value is used). All parameter estimates are statistically significant at least at the 10% level. Weighted regression is used with merged *CIS-ARD* data. Values of diagnostic tests are the same as in Table 3-19. For variable definitions, see Table 3-1.

Above all, the complementarity is found to be very important in businesses’ R&D ‘make’ or ‘buy’ choices in the UK non-manufacturing. More specifically, establishments that undertake in-house R&D activity have significantly higher levels of R&D spending per unit of sales, vis-à-vis the comparison group – ‘R&D buy-in only’ sub-group. For instance, those invest in both intramural and extramural ‘buy-in’ R&D have (*cet. par.*) the highest levels of R&D intensity – they spend nearly 5 times more on R&D per unit of sales in relation to those that only ‘buy-in’ external R&D. Moreover, those establishments that are involved in ‘make’, ‘buy-in’ and cooperating in R&D invest more than 2.5 times more in R&D activity per unit of overall sales; whilst those that conduct in-house R&D only enjoy almost 1.8 times higher R&D intensity, vis-à-vis those purchasing external R&D only.

Notably, in line with the negative size impact on R&D intensity for UK manufacturing, Table 3-20 indicates that for those establishments participating in R&D activity, larger establishments spend less on R&D per unit of sales. For instance, the largest establishments (with 200+ employees) spend 81% less on R&D activity in relation to those smallest establishments (with less than 10 employees). In line with this establishment-level size effect, those establishments that belong to multi-plant firms tend to experience a similarly negative impact of business size on their R&D spending (note, this impact is different to the case with manufacturing). In a similar vein, labour productivity tends to be associated lower levels of R&D intensity; more specifically, a £1000 increase in turnover per employee in the establishment decreases (*cet. par.*) its R&D intensity by 0.8[61]. Again, this negative impact of enterprise size (conditional on being multi-plant firms) and labour productivity could be interpreted as mirroring the negative size effect.

Surprisingly, various absorptive capacity indices seem to have a negative impact on establishment's R&D intensity for UK non-manufacturing (despite the relatively small magnitude). Another unexpected result is regarding the barriers to innovation variables: lack of customer responsiveness, quoted as a potential factor hampering innovation, seems to have a positive effect on R&D spending per unit of sales. On the other side, other factors that have a significantly positive role in determining R&D intensity include industry and ownership characteristics. For instance, if the establishment belongs to an industry with a high degree of agglomeration and/or has a high level of product diversification, it invests (*cet. par.*) more in R&D per unit of sales. What's more, being owned by US enterprises substantially increases (*cet. par.*) establishments R&D spending per unit of sales by more than 10 times.

As with the case of manufacturing, sector and region also seem to have a role to play. For instance, negative impact on R&D intensity is identified in establishments operating in construction and transport industries, as well as being located in the North East of England.

[61] Note, as opposed to the case with manufacturing, no information is available on the age and capital of establishments.

Finally, in terms of the impact of exporting on R&D expenditure, as with the case of manufacturing sector, whether an establishment exports or not, on average, fails to exert any influence on its R&D spending in the non-manufacturing sector. However, as evident before, more export-oriented establishments do seem to suggest a distinct R&D behaviour. As the results suggest in Table 3-29 (in the Appendix), establishments predominantly producing for overseas markets spend on average (*cet. par.*) around 366% more on R&D per unit of sales, even after such endogeneity has been taken into account. This seems to imply a more pronounced impact of strong export orientation in the non-manufacturing sector compared with the manufacturing.

3.3.3 Conclusions

As reviewed in Chapter 2, the literature relating to trade and innovation tends to imply that in order to break down barriers to internationalisation, firms need to invest in R&D and/or other innovative resources to produce diversified products for international markets. This dimension to the export-R&D nexus has been tested in the first part of this Chapter (pp.83-111) confirming R&D being a significant determinant of export. This section further examines the other direction of this export-R&D relationship (i.e. exporting status as a determinant of R&D behaviour).

Empirical results obtained here suggest whether exporting takes place or not, on average, does not seem to have any (*cet. par.*) impact on R&D activity (in either manufacturing or non-manufacturing sector in the UK), once the endogenous nature of exports is taken account of using appropriate techniques in the econometric modelling. Nevertheless, this could be partly due to the fact that only around 26% of UK establishments actually had any exposure to international markets, with an average export intensity of less than 7% in 2000. Indeed, if the relationship under investigation is between R&D activity and strong export orientation (defined as production mainly serving overseas markets), such intense export behaviour is found to have a major impact on the establishment's R&D behaviour (be either the probability to spend on R&D or the intensity of such activity), even after controlling for the endogeneity. Indeed, the results indicate that, taking into account the endogenous nature of the relationship, establishments that are predominately producing for international markets are *cet. par.* 4% (in non-manufacturing) and 5% (in manufacturing) more likely to undertake R&D activity; whereas conditional on R&D taking place, on average, such strong export orientation further boosts R&D expenditure (as a percentage of sales) by 183% (in manufacturing) and 366% (in non-manufacturing).

Other likely determinants of whether R&D spending takes place and how much is spent on R&D are based on the review of literature and whether they are practically available in the current *CIS3-ARD* database. In a similar Heckman setting, various factors included are tested here and the key results are as follows.

As with exporting, the establishment size has a major impact on whether R&D expenditure takes place or not. Industrial sector in which the establishment operates also matters, presumably reflecting distinct technological opportunities available across industries. Certain barriers mostly linked to high cost of innovation and lack of information on markets/customers impact on whether R&D is undertaken or not, although the magnitude of such impact is relatively small. Various aspects of absorptive capacity are mostly important in determining whether an establishment engages in R&D spending, although the most crucial dimension is the capacity for absorbing and utilising external knowledge, reinforcing the notion of complementarity between internal and external knowledge in fostering innovation.

Moreover, establishments that receive public sector support appear significantly more likely to spend on R&D compared with those not receiving assistance. However, the model has not identified any statistically significant benefits of foreign ownership, industry/market characteristics (e.g. degree of agglomeration/concentration), intra-industry spillover of R&D activity, etc.

As to what determines the level of R&D spending per unit of total sales, the findings are summarised below. Above all, various strategic options of acquiring R&D are introduced and tested at this second stage of modelling, so as to shed light on the inter-relationship amongst different R&D choices facing businesses. The results obtained show that establishments that ‘buy-in’ R&D are associated with significantly lower levels of R&D spending vis-à-vis those engaged in intramural R&D spending. What's intuitively appealing, the combination of both intramural and extramural R&D acquisition renders businesses even higher R&D intensity (in relation to conducting in-house R&D alone), combining the strategies of 'make', 'buy-in' and co-operate with others to acquire innovative resources.

In line with the empirical evidence on the non-linear R&D-size relationship documented in the literature (see the review in Chapter 2, pp. 41-44), conditional on successful participation in R&D activity, larger establishments are found to spend less on R&D per unit of sales, partly because the nature of R&D in larger establishments is more process (than product) oriented and therefore requires lower levels of relative spending. Sector plays an even more crucial role in affecting R&D spending than deciding the first stage of whether to invest in R&D or not. In additional to the direct negative size-R&D intensity linkage, some other size-related establishment-specific characteristics (such as labour productivity and age for manufacturing sector) are also found to reduce R&D intensity, probably simply mirroring such negative size effect.

In terms of factors hampering innovation, the high direct cost of innovation continues to have an adverse impact upon R&D intensity, further to its negative influence on R&D propensity. On the other side, for manufacturing, establishments that have higher capital intensity or receive public sector support spend (*cet. par.*) more on R&D per unit of sales compared to those not receiving assistance.

Lastly, only one type of absorptive capacity (namely, that for scientific knowledge) appears to be significantly beneficial to R&D spending for establishments in the manufacturing sector, although results of absorptive capacity are generally atypical for the non-manufacturing sector.

All in all, business spending on R&D is dominated by the manufacturing sector; less than 26% of total spending in 2001 was dedicated to the non-manufacturing sector. However, the results are found to be broadly similar across the manufacturing and non-manufacturing sectors with respect to the impact of the key determinants of R&D.

Appendix

Description of the ARD and CIS Datasets

- **The Annual Respondents Database (*ARD*)**

The Annual Respondents Database (ARD, currently available from 1973-2005) provides the most extensive micro data for the UK, constructed from the Annual Business Inquiry (ABI) from 1998 onwards and other previous source surveys prior to 1998, such as the Annual Census of Production (ACOP) and Annual Censuses of Production and Construction (ACOC). In particular, the ABI is a compulsory business survey that compiles the most comprehensive information covering numerous aspects of businesses in the UK[62], such as costs, turnover, employment levels, purchases, net capital expenditure, industry, location and ownership, etc. This survey is often used for the purposes of constructing the National Accounts and generating industrial statistics.

In terms of its coverage, the *ARD* data prior to 1993 contain mainly construction sectors and since 1998 more industries are surveyed to cover the vast majority of production and construction businesses. Nevertheless, the *ARD* only covers services sector since 1997, when it starts to hold responses from six other former surveys regarding distribution and other service activities. The surveys discussed above are linked over time using the Inter Departmental Business Register (IDBR) to create the *ARD*, which is a census of large businesses, and a sample of smaller ones. The IDBR includes about 98% of business activity (by turnover) in Great Britain. A stratified sample is drawn for the conduction of the ABI on an annual basis, and thus the *ARD* holds business responses to the surveys sent by the ONS. Meanwhile, the IDBR also records data from the administrative sources of VAT and PAYE records for all of the some 3.7 million businesses. For the sectors covered by ACOP/ABI most of these administrative data are also stored on the *ARD*, so that weights could be created to allow the whole population to be taken into account when conducting analysis using the *ARD*. In contrast, smaller firms may receive a 'short form', which asks fewer questions. Therefore respondents

[62] Note, the ABI data for Northern Ireland from the ONS covers the period 1998-2001. From 2002 onwards, the ABI for Northern Ireland (NI ABI) is collected independently and stored separately by the Department of Enterprise, Trade and Investment (DETI) in Northern Ireland.

are not required to return detailed break-down of the totals and thus the values for certain variables may have to be estimated or imputed based on other sources.

Given the sampling frame, weights are available to allow each business to be representative of a number of similar businesses, based on the employment and the industrial classification (SIC). Table 3-21 below gives a picture of the sampling frame used in the *ARD*.

Table 3-21: Sampling in *ARD* source data, 1970-2000

Survey year	Employment size band	Sampling fraction	Comments
1970-1971	<25 25 or more	0 (exempt) All	In some industries, <11 In some industries 11 was lower limit.
1972-1977	<20 20 or more	0 (exempt) All	
1978-1979	<20 20-49 50 or more 20 or more	0 (exempt)[a] 0.5 All All	All industries In 68 industries In 68 industries In all other industries
1980-1983	<20 20-49 50-99 100 or more	0 (exempt) 0.25 0.5 All	All industries In most industries In most industries All industries
1984	<20 20-49 50 or more	0 (exempt) 0.5 All	All industries England only 20 or more outside England
1985-1988	<20 20-49 50-99 100 or more	0 (exempt) 0.25 0.5 All	All industries In most industries In most industries All industries
1989	<20 20-49 50 or more	0 (exempt) 0.5 All	All industries England only 20 or more outside England
1990-1994	<20 20-49 50-99 100 or more	0 (exempt) 0.25[b] 0.5 All	All industries In most industries In most industries All industries
1995-1997	<10 10-49 50-99 100-199 200 or more	0.2 0.25 0.5 0.75 All	50% of industries, others with smaller thresholds
1998 onwards	<10 10-99 100-249 250 or more	0.25 0.5 All or <= 0.5 All	Varies by industry

Notes: For 1997 and earlier years these are sampling frames for ACOP. From 1998 onwards they refer to ABI. [a] In 1978 a small sample of establishments employing less than 20 was also drawn. [b] 0.2 in 1993.
Source: *ARD* User Guide, ONS (2002); also Oulton (1997) and Barnes and Martin (2002)

The structure and known issues with the *ARD* have been discussed in detail in recent applied work using this data source, such as Oulton (1997), Griffith (1999) and Harris (2002, 2005). Analyses previously undertaken employing the *ARD* cover a range of areas, for instance, productivity (Harris and Robinson, 2003);

entry, exit, closure and growth (*c.f.* Harris and Drinkwater, 2000; Harris and Hassaszadeh, 2002; and Disney *et al.*, 2003); foreign ownership (*c.f.* Harris and Collins, 2005; and Harris and Robinson, 2003); industrial policy (*c.f.* Harris and Robinson, 2004); and environmental issues (*c.f.* Chapple *et al.*, 2005; and Harris and Collins, 2005). The counterpart to the *ARD* in the US is the Longitudinal Research Database – or LRD – for US manufacturing provided through the US Bureau of Census. This has been analysed fairly extensively in recent years, covering various areas linked to productivity (*c.f.* Bartelsman and Dhrymes, 1998); capital efficiency (*c.f.* Doms, 1996); entry and exit (*c.f.* Doms *et al.*, 1995; Olley and Pakes, 1996) and lastly, the impact of ownership change on productivity (McGuckin and Nguyen, 2001).

- **The Community Innovation Survey (*CIS*)**

The Community Innovation Survey 2001 (*CIS3*) is a cross-sectional survey of innovation covering the 1998-2000 period, including the characteristics of the reporting unit surveyed, such as turnover, employment, investment in various kinds of innovative activity (e.g. product, process and wider innovation), effects of innovation, sources of information and cooperation, barriers to innovation, public support for innovation and, most importantly with respect to this study, exports. Like all other *CIS* series, this survey is collected by the ONS on behalf of the DTI.

The *CIS* comprises of a stratified sample of establishments with more than 10 employees, drawn from the IDBR, which are selected by SIC92 2-digit class and 8 employment size bands. The survey covers all market-based sectors, including manufacturing, mining, electricity, gas and water, construction and the service sectors.

The *CIS3* survey only achieved 42% response rate, but the weights computed ensure the sample obtained is representative of the population of all UK establishments. Of course, there may be sample bias if those who did not respond are not a random sub-group of all establishments who were sent the survey questionnaire. Nevertheless, this would be a generic problem, and not particular to the *CIS3* (and with no specific implications for merging the *CIS3* and *ARD* datasets). Other researchers have compared the distribution of R&D across industries from the *CIS* data and the Business Enterprise Research and Development (*BERD*), finding they have a high correlation (implying the *CIS* data is representative of the population of firms engaged in R&D).

The more up-to-date Community Innovation Survey 2005 (*CIS4*) is also available; however, the primary reason for not using this 2005 version is that it does not contain information on how much is sold abroad (only whether the establishment is engaged in exporting activities), and thus cannot be used to study the intensity of exporting for the purpose of the kind of analysis undertaken in this chapter.

Merging the CIS3 and ARD and Related Issues

Linking the *ARD* into the *CIS3* is possible, since IDBR reference numbers are common to both datasets. Notably, *ARD* data used here is at reporting unit (i.e. establishment) level to ensure comparability with the *CIS3* data. Where necessary, plant-level *ARD* information (e.g. on capital stocks in manufacturing) has been aggregated to reporting unit level. Moreover, the 2000 *ARD* data is used as the 2001 *CIS3* sample is drawn from the 2000 version of the IDBR, and thus matches ABI (and thus *ARD*) data on establishments operating in that year.

Thus ancillary information (particularly on ownership and spatial characteristics) available in the *ARD* has been added to the *CIS3* data for use in the subsequent analysis of what determines exporting/innovation. Of the 8172 reporting units covered in *CIS3*, it is possible to locate 7709 of these in the *ARD*. Non-matched observations mostly belong to those sectors not covered in the *ARD* (e.g. financial intermediation).

Chesher and Nesheim (2004) discuss the implications for statistical analysis of matching datasets, and in particular (in light of this study) consider the following:

- The impact of contributing survey designs and non-response on achieved linked survey design and implications for inference;
- Measurement error issues arising because of imputation of low level (e.g. plant) values using high level (e.g. business) values;
- The impact of excluding unmatched units in linked survey datasets

The second issue can be dealt with immediately, since matched data for 2000 from the *ARD* and *CIS3* are available at the establishment level, all analyses are based on establishment-level data, and both datasets are collected at this level of aggregation (rather than at a lower – e.g. plant – or higher – e.g. enterprise – level). Thus, there are no substantive issues due to imputation.

The third issue is also relatively unimportant, since in this study data from the *ARD* has been matched into the *CIS* dataset (not the other way around), and while it is not possible to match *ARD* data to all the 8,172 reporting units covered in *CIS3*, 7,709 of these could be located in the *ARD*. Nearly 77% of the unmatched units are in the financial intermediation sector (SIC65 under the 1992 SIC), and this sector is not covered by the *ARD*. Thus financial intermediation has been omitted from this study.

With respect to the first issue, throughout the *CIS3* has been used as the dataset representing the population of reporting units in the UK. All the analyses therefore use the weights available in the *CIS3* to ensure that the dataset is representative of UK establishments existing in 2000.

Therefore, it could be argued that subject to the normal caveats associated with using a sample dataset (the CIS), there are no major issues that are associated with merging the *ARD* into this data, with regard to the analyses conducted in this chapter.

The Heckman Model as in the Estimation of Exporting Orientation

The regression model relating to exporting intensity to be estimated is –

$$y_i = \mathbf{x}_i\beta + u_{1i}; \qquad u_1 \sim N(0,\sigma) \tag{3.1}$$

while the selection model that determines whether exporting takes place is estimated using the following probit equation –

$$p_i = \mathbf{z}_i\alpha + u_{2i};\ u_2 \sim N(0,1) \tag{3.2}$$

where p = 0 if exporting = 0 and p = 1 if exporting > 0. Thus the dependent variable y_i (in this case exporting intensity) is only observed if –

$$\mathbf{z}_i\alpha + u_{2i} > 0 \tag{3.3}$$

The expected value of the dependent variable in (3.1) is conditional on selection, which can be expressed as –

$$E[y_i \mid \mathbf{x}_i, p = 1]\,;\; corr(u_1, u_2) = \rho \tag{3.4}$$

Thus, estimating the regression model equates to estimating the following model–

$$\begin{aligned} E[y_i \mid \mathbf{x}_i, p = 1] &= E[y_i \mid \mathbf{x}_i, \mathbf{z}_i\alpha + u_{2i} > 0] \\ &= \mathbf{x}_i\beta + E[u_{1i} \mid u_{2i} > -\mathbf{z}_i\alpha] \\ &= \mathbf{x}_i\beta + (\rho\sigma)[\phi(\mathbf{z}_i\alpha)/\Phi(\mathbf{z}_i\alpha)] \end{aligned} \tag{3.5}$$

where ϕ is the normal density function and Φ is the standard cumulative normal distribution function. The parameter coefficient ρ measures the correlation between the error terms u_1 (from the regression model (3.1)) and u_2 (the selection model (3.2)); while σ measures the standard deviation of the residuals u_1. It is common to denote $\lambda = \rho\sigma$ as the composite parameter estimate for the term in square brackets, which is known as the inverse of the Mills' ratio. Estimating Equation (3.1) rather than (3.5) would lead to biased estimates of $\hat{\beta}$ unless ρ = 0. Thus since observing y_i (exporting intensity) is conditional on exporting taking place (i.e. exporting > 0), the additional term in (3.5) representing the inverse of the Mills' ratio takes account of the fact that those that do export are not a random sample of the population of all establishments; in fact, those that do export, such that y_i is observed, overcome a threshold that makes it 'worthwhile' to export, with this threshold being given by Equation (3.3).

Additional Estimation Results

Table 3-22: Reduced-form models of exporting, R&D and R&D continuous in UK manufacturing, 2000 (in support of the modelling of exporting)

	Exporting undertaken or not		R&D undertaken or not		R&D continuous		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value		*z*-value	Means ($\bar{x}$)
Establishment size							
10-19 employees	0.087*	1.70	***0.099****	2.28	0.028	0.93	0.265
20-49 employees	0.255***	5.40	0.107***	2.73	0.018	0.65	0.356
50-199 employees	0.381***	8.67	0.141***	2.94	0.093**	2.42	0.215
200+ employees	0.442***	10.86	0.176***	2.78	0.195***	3.20	0.074
ln enterprise size **X** Multi-plant	-0.016**	-2.55	0.000	0.12	0.002	0.86	3.529
ln establishment age	-0.006	-0.49	***-0.014****	-2.06	***-0.009****	-1.71	1.158
Absorptive capacity							
Absorptive capacity (ext. knowledge)	0.085***	6.73	***0.119*****	14.59	***0.072*****	11.02	0.133
Absorptive capacity (national co-op)	0.039***	2.61	***0.036*****	6.83	***0.018*****	3.89	0.029
Absorptive capacity (org structure & HRM)	0.048***	4.08	0.045***	7.17	***0.036*****	7.23	0.057
Absorptive capacity (international co-op)	0.069***	3.28	0.021***	4.22	***0.021*****	4.59	0.050
Absorptive capacity (scientific knowledge)	0.077**	2.40	0.002	0.28	0.010	1.50	-0.007
ln Capital/employment ratio (ARD data)	0.030**	2.30	0.018**	2.50	***0.016*****	2.89	-5.645
ln Labour productivity (£'000 per worker)	0.107***	5.80	-0.009	-1.03	0.003	0.44	4.089
Industry agglomeration	0.008**	2.01	0.002	1.45	-0.001	-0.57	1.456
ln Herfindahl index	0.0768***	4.45	-0.002	-0.19	-0.001	-0.11	-2.899
ln Density ('000 per hectare)	-0.011	-1.27	0.004	0.77	-0.006	-1.58	1.986
Received public sector support	0.007	0.18	***0.086*****	3.19	***0.067*****	2.82	0.104
Ownership characteristics							
US-owned	0.095	0.94	-0.033	-0.95	***-0.049*****	-3.51	0.014
Barriers to innovation							
Lack of info on technology	0.044	0.82	-0.035	-1.37	***-0.057*****	-4.81	0.056
Lack of customer responsiveness	-0.002	-0.06	***-0.037****	-2.22	-0.001	-0.05	0.121
High cost of innovation	-0.011	-0.42	***-0.037*****	-2.57	***-0.033*****	-2.95	0.256
Impact of regulations/standards	-0.087***	-2.66	0.008	0.39	0.008	0.56	0.165

Table 3-22 (cont.)

	Exporting undertaken or not		R&D undertaken or not		R&D continuous		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	Means ($\bar{x}$)
Industry sector (2-digit 1992 SIC)							
Food & drink	0.303***	3.12	-0.008	-0.15	***0.245****	2.39	0.074
Textiles	0.516***	11.21	0.018	0.26	***0.239****	2.13	0.040
Clothing & leather	0.398***	4.62	0.013	0.16	***0.215****	1.69	0.032
Wood products	0.299***	2.84	0.049	0.61	0.072	0.81	0.040
Paper	0.373***	4.26	0.044	0.54	0.094	1.12	0.030
Publishing & printing	0.241**	2.26	-0.039	-0.81	0.073	1.06	0.113
Chemicals	0.521***	11.79	0.130	1.30	***0.331*****	2.67	0.037
Rubber & plastics	0.523***	10.56	0.108	1.20	***0.179****	1.82	0.065
Non-metallic minerals	0.321***	3.12	-0.032	-0.63	0.123	1.26	0.033
Basic metals	0.504***	10.02	0.063	0.68	0.131	1.24	0.027
Fabricated metals	0.452***	5.37	0.008	0.13	0.050	0.85	0.186
Machinery & equipment nes	0.516***	8.66	0.128	1.46	0.221**	2.22	0.104
Electrical machinery	0.532***	11.50	0.112	1.32	0.308***	2.86	0.071
Medical etc instruments	0.511***	11.23	0.013	0.20	0.403***	3.30	0.035
Motor & transport	0.433***	6.26	-0.002	-0.04	0.211**	2.03	0.039
Furniture & manufacturing nes	0.442***	6.23	0.060	0.80	***0.266****	2.47	0.067
Region							
Eastern England	0.074*	1.72	***0.057****	1.90	0.018	0.91	0.086
Northern Ireland	0.232***	3.08	-0.025	-0.57	0.022	0.48	0.020
South East	-0.019	-0.49	0.022	0.98	***0.049****	2.33	0.106
South West	-0.032	-0.79	0.028	1.04	0.045*	1.86	0.076
Scotland	-0.052	-1.34	-0.020	-0.94	-0.028*	-1.94	0.092
(unweighted) N	3303		3303		3303		

Notes: Weighted probit models used. ***Significant at 1%, ** significant at 5%, *significant at 10% level. Highlighted parameter estimates (bold and italics) denote which variables act as the key instruments when R&D and continuous R&D are treated as endogenous.

Table 3-23: Reduced-form models of exporting, R&D and R&D continuous in UK non-manufacturing, 2000 (in support of the modelling of exporting)

	Exporting undertaken or not		R&D undertaken or not		R&D continuous		
	$\partial\hat{p}/\partial x$	z-value	$\partial\hat{p}/\partial x$	z-value	$\partial\hat{p}/\partial x$	z-value	Means ($\bar{x}$)
Establishment size							
10-19 employees	0.025	1.23	***0.032*****	2.04	-0.001	-0.13	0.346
20-49 employees	0.106***	4.50	0.039**	2.40	0.001	0.14	0.322
50-199 employees	0.124***	3.95	0.036*	1.82	0.010	0.98	0.136
200+ employees	0.260***	4.79	0.090**	2.34	0.087**	2.43	0.031
ln enterprise size **X** Multi-plant	-0.021***	-5.07	0.003	1.10	-0.003*	-1.73	0.795
Absorptive capacity							
Absorptive capacity (ext. knowledge)	0.017***	3.06	0.056***	12.80	0.023***	8.40	-0.088
Absorptive capacity (national co-op)	0.004	0.68	***0.014******	3.93	***0.003*****	2.06	-0.033
Absorptive capacity (org structure & HRM)	0.013**	2.43	0.022***	6.42	0.010***	5.10	-0.048
Absorptive capacity (international co-op)	0.009*	1.64	0.013***	3.41	0.004***	2.70	-0.051
Barriers to innovation							
Lack of info on technology	-0.045**	-2.21	-0.030***	-2.58	-0.001	-0.09	0.042
High cost of innovation	-0.005	-0.36	0.013	1.24	***0.011***	1.54	0.168
Other factors							
ln Labour productivity (£'000 per worker)	0.035***	6.42	0.000	-0.09	0.000	0.15	4.282
Industry agglomeration	0.005***	2.73	-0.001	-0.43	0.000	0.12	0.784
ln Herfindahl index	-0.017***	-2.62	0.003	0.71	-0.003	-1.03	-2.994
ln Density ('000 per hectare)	0.001	0.28	0.002	0.77	***-0.003****	-1.76	2.078
Operated in >1 SIC	0.034**	2.16	0.000	-0.02	0.000	-0.01	0.149
Multi-plant enterprise >1 region	0.114***	3.32	-0.021**	-1.97	-0.001	-0.17	0.085
Received public sector support	0.012	0.47	***0.056******	2.63	***0.023****	1.77	0.052

Table 3-23 (cont.)

	Exporting undertaken or not		R&D undertaken or not		R&D continuous		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	Means ($\bar{x}$)
Industry sector (2-digit 1992 SIC)							
Construction	-0.047*	-1.85	***-0.026****	-1.98	***-0.022*****	-3.10	0.246
Wholesale trade	0.260***	5.56	-0.005	-0.33	-0.004	-0.44	0.247
Transport	-0.033	-1.19	-0.022*	-1.63	***-0.018*****	-3.40	0.085
Transport support	0.081*	1.63	-0.032***	-2.68	-0.004	-0.35	0.040
Financial services	0.063	0.41	***0.385****	1.67	***0.451****	1.69	0.001
Real Estate	-0.097***	-7.39	-0.013	-0.71	-0.009	-0.93	0.047
Computing	0.288***	4.02	0.095**	2.26	0.116**	2.38	0.042
Other business services	0.139***	3.44	0.023	1.26	0.004	0.35	0.244
Region							
North West	-0.026*	-1.81	-0.007	-0.61	-0.001	-0.15	0.100
South East	0.034**	1.96	0.000	0.02	0.002	0.26	0.134
South West	-0.055***	-3.23	-0.008	-0.61	-0.005	-0.80	0.077
(unweighted) N	4007		4007		4007		

See Table 3-22 for notes.

Table 3-24: Reduced-form models of exporting and R&D in UK manufacturing, 2000 (in support of the modelling of R&D)

	Exporting undertaken or not		R&D undertaken or not		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	Means ($\bar{x}$)
Establishment size					
10-19 employees	0.083*	1.62	0.103**	2.36	0.265
20-49 employees	0.256***	5.39	0.108***	2.74	0.356
50-199 employees	0.382***	8.65	0.140***	2.91	0.215
200+ employees	0.445***	11.09	0.168***	2.70	0.074
ln enterprise size **X** Multi-plant	***-0.023****	-3.18	0.000	-0.01	0.921
Absorptive capacity					
Absorptive capacity (external knowledge)	0.085***	6.75	0.120***	14.60	0.133
Absorptive capacity (national co-op)	0.040***	2.67	0.036***	6.99	0.029
Absorptive capacity (org structure & HRM)	0.049***	4.12	0.045***	7.07	0.057
Absorptive capacity (international co-op)	0.069***	3.24	0.021***	4.04	0.050
Absorptive capacity (scientific knowledge)	***0.078****	2.43	0.001	0.23	-0.007
Factors hampering innovation					
Lack of customer responsiveness	0.000	0.01	-0.039**	-2.33	0.121
High cost of innovation	-0.006	-0.23	-0.039***	-2.76	0.256
Impact of regulations	***-0.083****	-2.57	0.006	0.33	0.165
Other factors					
ln Age	-0.006	-0.49	-0.014*	-1.94	1.158
ln Capital/employment ratio (ARD data)	0.030**	2.31	0.018**	2.47	-5.645
ln Labour productivity (£'000 per worker)	***0.105****	5.79	-0.009	-1.03	4.089
Industry agglomeration	0.007*	1.91	0.002	1.34	1.456
ln Herfindahl index	0.077***	4.51	-0.002	-0.22	-2.899
Received public sector support	0.004	0.09	0.085***	3.17	0.104
Industry sector (2-digit 1992 SIC)					
Food & drink	***0.291****	2.99	-0.014	-0.25	0.074
Textiles	***0.512****	10.85	0.011	0.17	0.040
Clothing & leather	***0.388****	4.45	0.012	0.14	0.032
Wood products	***0.291****	2.76	0.040	0.52	0.040
Paper	***0.356****	3.93	0.040	0.51	0.030
Publishing & printing	***0.225****	2.12	-0.038	-0.80	0.113
Chemicals	0.516***	11.34	0.127	1.30	0.037
Rubber & plastics	0.518***	10.28	0.105	1.18	0.065
Non-metallic minerals	***0.311****	3.01	-0.036	-0.72	0.033
Basic metals	***0.498****	9.61	0.056	0.62	0.027
Fabricated metals	***0.443****	5.25	0.006	0.10	0.186
Machinery & equipment nes	0.512***	8.56	0.124	1.44	0.104
Electrical machinery	0.526***	11.05	0.113	1.35	0.071
Medical etc instruments	***0.505****	10.78	0.015	0.23	0.035
Motor & transport	***0.428****	6.20	-0.004	-0.07	0.039
Furniture & manufacturing nes	0.436***	6.10	0.058	0.79	0.067
Region					
Eastern England	0.095**	2.29	0.050*	1.78	0.086
Northern Ireland	***0.261****	3.68	-0.032	-0.81	0.020
Greater South East	***0.144****	2.42	0.005	0.16	0.040
(unweighted) N	3303		3303		

Notes: Marginal effects are reported in these weighted probit models; for a binary variable, this refers to the discrete change of this variable from 0 to 1. Highlighted parameter estimates (bold and italics) denote which variables act as the key instruments when 'export' is treated as endogenous. ***Significant at 1%, ** significant at 5%, *significant at 10% level.

Table 3-25: Reduced-form models of exporting and R&D in UK non-manufacturing, 2000 (in support of the modelling of R&D)

	Exporting undertaken or not		R&D undertaken or not		
	$\partial\hat{p}/\partial x$	*z*-value	$\partial\hat{p}/\partial x$	*z*-value	Means ($\bar{x}$)
Establishment size					
10-19 employees	0.024	1.22	0.033**	2.08	0.346
20-49 employees	0.106***	4.50	0.040**	2.45	0.322
50-199 employees	0.125***	3.97	0.037*	1.84	0.136
200+ employees	0.262***	4.85	0.090**	2.34	0.031
ln enterprise size **X** Multi-plant	***-0.021****	-5.13	0.003	1.01	0.795
Absorptive capacity					
Absorptive capacity (external knowledge)	0.016***	3.04	0.057***	13.09	-0.088
Absorptive capacity (national co-op)	0.004	0.66	0.014***	4.05	-0.033
Absorptive capacity (org structure & HRM)	0.013**	2.47	0.023***	6.58	-0.048
Absorptive capacity (international co-op)	0.010*	1.67	0.014***	3.52	-0.051
Factors hampering innovation					
Lack of info on technology	***-0.046****	-2.32	-0.028**	-2.26	0.042
Other factors					
ln Labour productivity (£'000 per worker)	***0.036****	6.50	0.000	-0.10	4.282
Industry agglomeration	***0.005****	2.74	0.000	-0.22	0.784
ln Herfindahl index	***-0.016****	-2.45	0.004	1.01	-2.994
Operated in > 1 SIC	***0.034****	2.18	0.000	0.04	0.149
Multi-plant enterprise > 1 region	***0.116****	3.36	-0.020*	-1.83	0.085
Received public sector support	0.012	0.48	0.055***	2.63	0.052
Industry sector (2-digit 1992 SIC)					
Construction	-0.028	-1.26	-0.015	-1.25	0.246
Wholesale trade	***0.298****	8.50	0.010	0.72	0.247
Transport support	0.115**	2.49	-0.024*	-1.70	0.040
Financial services	0.091	0.53	0.447*	1.88	0.001
Real estate	***-0.092****	-5.95	0.001	0.07	0.047
Computing	0.340***	5.68	0.131***	3.23	0.042
Other business services	0.174***	5.66	0.043***	2.66	0.244
Region					
North West	***-0.026****	-1.81	-0.007	-0.54	0.100
South East	***0.033****	1.95	-0.001	-0.09	0.134
South West	***-0.056****	-3.36	-0.009	-0.70	0.077
(unweighted) N	3303		3303		

See Table 3-24 for notes.

Table 3-26: Determinants of R&D spending in UK manufacturing, 2000 (an alternative estimation to Table 3-16)

Dependent variable: R&D undertaken or not	Model 1		Model 2	
	$\partial\hat{p}/\partial x$	z-stat	$\partial\hat{p}/\partial x$	z-stat
Largest market international	0.158	4.94	0.054	2.50
Establishment size				
10-19 employees	0.075	2.57	0.085	2.73
20-49 employees	0.093	3.50	0.102	3.64
50-199 employees	0.100	3.03	0.118	3.33
200+ employees	0.106	2.74	0.132	2.87
Other factors				
Absorptive capacity	0.119	14.84	0.123	14.37
Largest market national	0.076	4.78	0.030	2.74
High cost of innovation	–	–	-0.028	-1.86
International co-op	0.141	3.53	0.153	3.29
Spillovers	0.009	2.62	0.009	2.25
Support	0.070	3.04	0.073	2.94
Region				
Eastern England	0.033	1.65	0.033	1.59
Industry (2-digit 1992 SIC)				
Food & drink	-0.050	-2.85	-0.054	-2.72
Publishing & printing	-0.043	-2.65	-0.048	-2.82
Non-metallic minerals	-0.054	-2.33	-0.061	-2.78
Fabricated metals	-0.031	-1.82	-0.038	-2.22
Medical etc instruments	-0.045	-2.29	-0.041	-1.83
Motor & transport	-0.039	-2.47	-0.037	-2.21
ρ	0.878	22.45	0.869	20.62
σ	1.875	11.97	1.867	11.77
λ	1.647	7.97	1.622	7.66
N	3372		3372	
N (rd > 0)	758		758	
Log pseudo-likelihood	-1884.3		-1904.61	
Wald test of independent equations $\chi^2(1)$	63.78		59.69	

Notes: Model 1 is the baseline model, while Model 2 controls for endogeneity of 'largest market international' (a proxy for strong exporting). Marginal effects are reported. The reported parameter estimates are all statistically significant at the 10% level. Weighted regression is used with merged *CIS-ARD* data. For variable definitions, see Table 3-1.

Table 3-27: Determinants of R&D intensity in UK manufacturing, 2000 (cont.) (an alternative estimation to Table 3-17)

Dependent variable: *ln* R&D intensity	Model 1		Model 2	
	$\hat{\beta}$	z-stat	$\hat{\beta}$	z-stat
Largest market international	1.119	3.91	1.039	6.43
Complementarity of R&D activities				
R&D Buy Only	-0.768	-5.68	-0.791	-5.84
R&D Make & Buy	0.748	4.91	0.734	4.76
R&D Buy & Cooperate	-0.748	-2.85	-0.815	-3.06
R&D Make & Buy & Cooperate	0.590	3.35	0.582	3.29
Undertook continuous R&D	0.900	7.43	0.935	7.67
Establishment size				
50-199 employees	-0.653	-4.03	-0.565	-3.41
200+ employees	-1.107	-5.45	-0.939	-4.11
Other factors				
Absorptive capacity	0.714	5.08	0.725	4.85
Single-plant enterprise	-0.460	-2.26	-0.406	-1.96
>1 region multiplant	-0.716	-3.28	-0.664	-3.02
>1 SIC multiplant	-0.291	-2.40	-0.300	-2.46
Diversification	-1.054	-1.67	-1.041	-1.67
Largest market national	0.546	2.30	–	–
High cost of innovation	-0.386	-2.36	-0.423	-2.46
International co-op	0.720	3.22	0.864	2.99
Support	0.806	4.57	0.847	4.41
Region				
Scotland	0.477	2.30	0.483	2.31
Industry (2-digit 1992 SIC)				
Food & drink	-1.541	-4.77	-1.682	-4.69
Wood products	-1.487	-4.16	-1.619	-3.98
Paper	-1.318	-6.20	-1.331	-6.35
Non-metallic minerals	-1.330	-3.44	-1.304	-3.33
Fabricated metals	-0.376	-1.84	-0.476	-2.26
Medical etc instruments	0.704	2.36	0.818	2.55

See Table 3-26 for notes.

Table 3-28: Determinants of R&D spending in UK non-manufacturing, 2000 (an alternative estimation to Table 3-19)

Dependent variable: R&D undertaken or not	Model 1		Model 2	
	$\partial\hat{p}/\partial x$	z-stat	$\partial\hat{p}/\partial x$	z-stat
Largest market international	0.112	3.99	0.041	1.63
Establishment size				
10-19 employees	0.014	1.47	0.016	1.61
20-49 employees	0.027	2.61	0.030	2.71
50-199 employees	0.020	1.70	0.019	1.54
200+ employees	0.052	2.41	0.061	2.57
Other factors				
Absorptive capacity	0.052	12.99	0.058	13.76
Largest market national	0.033	3.72	0.017	2.02
Impact of regulations	0.016	2.03	0.018	2.12
Lack of info on technology	-0.017	-2.04	-0.014	-1.28
International co-op	0.041	2.31	0.031	1.55
Support	0.055	3.00	0.060	2.97
Region				
North East	-0.023	-2.23	-0.026	-2.07
Industry (2-digit 1992 SIC)				
Construction	-0.049	-6.02	-0.057	-5.00
Wholesale trade	–	–	-0.047	-4.55
Transport	-0.041	-7.06	-0.045	-5.32
Transport support	-0.043	-9.26	-0.050	-9.68
Post & telecom	-0.027	-3.08	-0.032	-3.19
Financial	-0.047	-10.85	–	–
Real estate	-0.023	-2.49	-0.016	-0.86
Machine rentals	-0.030	-3.52	-0.032	-2.71
Other business	-0.022	-2.23	-0.029	-2.47
ρ	0.931	44.29	0.948	42.51
σ	2.449	11.98	2.585	9.92
λ	2.279	9.65	2.452	8.14
N	4387		4004	
N (rd > 0)	428		426	
Log pseudo-likelihood	-1922.1		-1924.7	
Wald test of independent equations $\chi^2(1)$	112.55		66.94	

See Table 3-26 for notes.

Table 3-29: Determinants of R&D intensity in UK non-manufacturing, 2000 (cont.) (an alternative estimation to Table 3-20)

Dependent variable: *ln* R&D intensity	Model 1		Model 2	
	$\partial\hat{p}/\partial x$	z-stat	$\partial\hat{p}/\partial x$	z-stat
Largest market international	2.034	5.51	1.538	5.56
Complementarity of R&D activities				
R&D Buy Only	-0.812	-4.21	-0.947	-5.16
R&D Make & Buy	0.793	2.55	0.708	2.21
R&D Buy & Cooperate	-0.810	-2.00	-0.889	-2.48
R&D Make & Buy & Cooperate	0.520	1.68	0.443	1.24
Undertook continuous R&D	0.356	1.74	0.476	2.28
Other factors				
ln enterprise size	-0.402	-4.44	-0.376	-4.71
Absorptive capacity	1.150	6.36	1.213	5.42
ln Herfindahl index	0.208	2.29	0.229	2.48
Largest market national	0.682	2.87	–	–
Support	0.934	3.20	1.059	3.38
Region				
North East	-1.157	-2.39	-1.140	-2.22
Industry (2-digit 1992 SIC)				
Construction	-1.684	-5.86	-1.944	-6.14
Wholesale trade	-1.769	-6.66	-1.682	-6.08
Transport	-1.733	-3.76	-1.676	-3.45
Transport support	-2.829	-5.56	-2.181	-3.73
Machine rentals	-1.175	-2.01	-1.090	-1.93
Computing	1.512	4.03	2.018	4.30
Other business				

See Table 3-26 for notes.

Chapter 4: Survey of the Literature on the Exporting-Productivity Relationship

In recent years, economics literature has paid close attention to characteristics of globalisation and how economies (and firms in particular) adjust to such changes. Exporting is believed to bring about several benefits from a firm's perspective including –

- Economies of scale and diversification of risks: increasing exposure to international markets leads to a higher demand for products. This may translate into an expansion in production, firm size and therefore the exploitation of economies of scale. On the other side, the diversification of products across countries equally may also reduce risk and encourage greater investment;

- International knowledge spillovers: as a public good, knowledge spillovers constitute a positive externality. Operating in global markets, firms that export are in a better position to exploit foreign knowledge spillovers and outperform their domestic counterparts. Moreover, there may well be positive spillover effects from exporting on indigenous non-participants, who can achieve higher technological standards more easily;

- Enhanced competency base: it is widely believed that international exposure will improve organisational efficiency in globalised firms due to international competition and the exploitation of external knowledge.

Productivity issues are central to analysing economic welfare, providing a clear policy context; therefore the relationship between international trade and productivity growth is crucial to understanding the firm's export orientation. The linkage between exporting and productivity has been extensively researched and well established in the macroeconomic literature, from the conventional Heckscher-Ohlin model to new trade models. More recently, almost evolving hand in hand with the RBV literature, a rapidly growing strand of the trade literature has focused on globalisation and its impacts on firms, exploiting the heterogeneity of individual firms. This section reviews this emerging literature on the relationship between export activity and productivity growth in light of firm-level heterogeneity, in an attempt to integrate the RBV perspective into the economics literature on exporting.

In conventional Heckscher-Ohlin type models, comparative cost theory is employed to explain the pattern of trade: as a consequence of trade, countries shift away from producing goods in most industries to producing goods in industries with comparative advantages. One of the most notable features of these models is that they assume homogenous productivity across countries – this substantial drawback has given rise to a new generation of trade models, the so called ‘new trade’ models (e.g. Krugman, 1980). An original contribution of Krugman’s model includes a consideration of the causes of trade between economies with similar factor endowments as well as the impact of a large domestic economy on export. This new framework incorporates scale economies, product differentiation and imperfect competition; nevertheless, based on the rather restrictive assumption of homogenous firms, it still fails to acknowledge the impact of differentiation in firm-level productivity.

These macroeconomics-oriented models, arguably, only provide a limited understanding of how individual firms behave in an increasingly globalised market, and thus their role in informing policy appears rather limited, which is, to a large extent, targeted at firms at the micro level. Recent years have seen a surge of interest in studying the microeconomic evidence such that there is now a rapidly growing literature seeking to understand how exporting impacts upon the firm’s behaviour and growth trajectory, taking into account the importance of heterogeneity among plants/firms. This emphasis on micro evidence has been partly triggered by the availability of quality data at the plant/firm level, as well as recent developments in the use of theoretical modelling and econometric techniques to exploit these inherently more intricate micro data.

In addition to offering new insights into firm-level exporting-productivity linkage, more recent micro studies also provide substantial theoretical underpinnings for a causal link between trade and productivity growth at the aggregate level[63]. For

[63] The macroeconomic literature on such a link between trade and aggregate productivity growth has been established earlier, see for instance, Grossman and Helpman (1991), Sachs and

instance, Bernard *et al.* (2003) provide an extension of Ricardian theory incorporating the importance of geographic (trade) barriers and imperfect competition in several countries. They find evidence for several basic facts about the US economy that cannot be justified by conventional trade theory: the much larger size and higher productivity of exporters; the rather small fraction of firms that actually export and of those that do exporting, the rather small fraction of their revenues that come from exporting.

In a seminal article, Melitz (2003) extends Krugman's (1980) model to accommodate firm-level differences in productivity in order to analyse the intra-industry effects of trade. It is shown that as a consequence of increasing exposure to trade, the most productive firms are induced to participate in export markets while less productive firms continue to serve the domestic market only; whereas the least productive firms drop out of the market. It follows that trade-induced reallocations towards more efficient firms will eventually lead to aggregate productivity gains. As an extension to Melitz's model to incorporate more than just exporting as an option when firms go global, Helpman *et al.* (2004) have predicted firms' sorting pattern according to their heterogenous productivity: the most productive firms set up overseas affiliates; the next most productive export; the less productive firms serve only the domestic market; whereas the least productive leave the industry. Other most recent international trade models incorporating firm-level heterogeneity also include Bernard *et al.* (2003) based on Ricardian differences in technological efficiency; Bernard *et al.* (2007) drawing on heterogeneous productivity; and Yeaple (2005) focusing on heterogeneous competing technologies, trade costs and labour skills.

4.1 The Exporting-Productivity Nexus at the Firm Level

There are several dimensions to how firms adjust to globalisation, with the most rapid growth in the literature concentrating on entry into international markets and whether this impacts upon firm-level productivity performance (and thus aggregate productivity growth). It is worth noting that 'productivity' is employed

Warner (1995), Ben-David and Loewy (1998), Edwards (1998) and Rodríguez and Rodrik (2000).

here not as the definitive, single characteristic that is crucial to exporting; from an RBV perspective, productivity used here serves more as a proxy for a range of firm-specific resources/capacities that distinguish a firm from others and thus impact directly upon the firm's performance. Such critical characteristics, for instance, could be absorptive capacity, resource bases, human/organisational capital, etc. (Baldwin and Gu, 2003).

Research on this exporting-productivity relationship was initially empirically driven and it is universally found in the literature that exporting is positively associated with firm performance (see Greenaway and Kneller, 2005 and 2007; and López, 2005, for excellent surveys and evidence). Nevertheless, despite this positive linkage, there is still much controversy about the causal direction of this link – whether causality runs from exporting to productivity, from productivity to exporting, or in both directions (i.e. a feedback relationship). These issues are often examined empirically by testing two competing (but not mutually exclusive) hypotheses, viz. self-selection and learning-by-exporting.

4.1.1 Self-Selection Hypothesis

The self-selection hypothesis assumes that plants that enter export markets do so because they have higher productivity prior to entry, relative to non-entrants. Underlying these selection effects is the substantial evidence of differences in characteristics between those that participate in export markets and those that do not. The general consensus based on evidence from a number of countries is that exporters are, on average, bigger, more productive, more capital intensive and pay higher wages vis-à-vis non-exporters (Baldwin and Gu, 2004; Girma *et al.*, 2004; Greenaway and Kneller, 2004). The reasons for export-oriented firms to exhibit better performance are intuitively appealing: since increasing international exposure brings about more intensive competition, firms that internationalise are forced to become more efficient so as to enhance their survival characteristics; meanwhile, the existence of sunk entry costs means exporters have to be more productive to overcome such fixed costs before they can realise expected profits.

The literature on whether firms that export 'self-select' into overseas markets provides strong evidence that this is indeed the case. Theoretical models developed by Clerides *et al.* (1998), Bernard *et al.* (2003) and Melitz (2003) consider exporting firms needing to be more productive prior to overseas entry in order to overcome the fixed (sunk) costs of entering export markets. López (2004) also develops a simple model in which forward-looking firms need to invest in new technology in order to become exporters, with the adoption of this technology requiring them to be more productive to begin with; put another way, from an RBV perspective, they need to have the resources – or absorptive capacity – that allows them to learn and internalise the new knowledge. As pointed out by Greenaway and Kneller (2005), the outcome then is that the most productive firms self-select into export markets; and the corollary is that firms have to become more productive before they enter such markets.

The empirical literature on self-selection of exporters has been recently surveyed by Greenaway and Kneller (2007) and Wagner (2007). Particularly, in some 30 studies reviewed in Greenaway and Kneller (2007, Table 3), covering a wide range of countries, 'self-selection' is universally found to be important. Nevertheless, there are still a few studies which find exporters are not more efficient than non-exporters: for instance, Bleaney and Wakelin (2002) with regard to UK manufacturing when controlling for innovating activity; Greenaway *et al.* (2005) for Swedish manufacturers with a relatively high level of international exposure on average; and Damijan *et al.* (2005) on firms in Slovenia where higher productivity is required only in those that export to advanced countries but not those who export to developing nations.

4.1.2 Learning-by-Exporting Hypothesis

Turning now to the 'learning-by-exporting' hypothesis, export-oriented firms are assumed to experience an acceleration in productivity growth following entry. If this is not true, this has important policy implications: if better firms do self-select into export markets, and exporting does not further boost productivity, then export subsidies could simply be a waste of resources (involving large-scale dead weight and possibly even displacement effects given that firms that export usually sell to domestic markets as well[64]).

[64] Robust empirical evidence shows that exporters tend to sell very small fractions of their output abroad (Roberts *et al.*, 1995).

The 'learning-by-exporting' proposition has, unfortunately, received somewhat less support in the literature. Many early empirical studies raised doubts about the causality running from exporting to productivity, since they find that productivity growth does not increase post entry, notwithstanding that exporting firms on average experience significantly higher growth in terms of employment and wages (Aw and Hwang, 1995, for Taiwan; Bernard and Jensen, 1995, for the US; Bernard and Wagner, 1997, for Germany; Clerides *et al.*, 1998, for Columbia, Mexico and Morocco; Delgado *et al.*, 2002, for Spain). For example, applying a novel non-parametric analysis of productivity distributions for Spanish firms, Delgado *et al.* (2002) fail to find significant differences between new exporters and continuing exporters by analysing the post-entry productivity growth distribution. Analogically, exporters are found to be no different from non-exporters, although limited learning effects could be found among younger exporters.

Consequently, many of the theoretical models developed in recent years have generally ignored any 'learning-by-exporting' effect, and instead concentrated on the implications of self-selection for overall aggregate productivity growth (*c.f.* Bernard *et al.*, 2003; Melitz, 2003; Yeaple *et al.*, 2005; and Bernard *et al.*, 2007)[65]. The major exception is Clerides *et al.* (1998) who develop a model that results in lower costs for exporters both as a result of pre-entry selection (to overcome barriers to exporting) and of learning that occurs during exporting. The latter can be justified on the grounds that, for example, exporting markets are more competitive, forcing firms to become more efficient (post- as well as pre-entry); while actual involvement in exporting could result in higher returns to innovating and so increase the incentives to develop new products and processes (Holmes and Schmitz, 2001). Simulations of average variable costs in Clerides *et al.* (*op. cit.*) confirm that both selection and 'learning-by-exporting' affect productivity in exporters, but the empirical evidence they have unveiled generally does not support the presence of learning effects post-entry[66].

[65] For example, Bernard *et al.* (2007) state in their Footnote 10 that they assume away any 'learning-by-exporting' effect since this matches previous empirical findings.

[66] The authors recognise this might be because they only empirically modelled labour and material costs and not total costs (including capital). Given the sunk costs associated with becoming an exporter, a different result might have been obtained if all factors costs had been included.

Nevertheless, some of the literature reviewed earlier (*c.f.* Chapter 1, pp.17-32) emphasises the importance of exporting as a learning process. From an RBV perspective, the process of going international is perceived as a sequence of stages in the firm's growth trajectory, which involves substantial learning (and innovating) through internal and external channels, so as to enhance its competence base and improve its performance. Thus, the 'learning-by-exporting' proposition is consistent with this literature reviewed on internationalisation.

Indeed, positive learning effects for firms engaged in exporting have been identified, particularly where different econometric methodologies are adopted that principally take account of selectivity effects (e.g. Kraay, 1999; Castellani, 2002; Hallward-Driemeier *et al.,* 2002; Pavcnik, 2002; Baldwin and Gu, 2003; Girm *et al.*, 2004; van Biesebroeck, 2005; Lileeva and Trefler, 2007; Fernandes and Isgut, 2007; and De Loecker, 2007). More recently, Crespi *et al.* (2008) have found that exporters in the UK engage in relatively more learning from clients, and that this subsequently leads to higher productivity growth[67].

For instance, using data from a sample of Chinese industrial enterprises, Kraay (1999) finds that past export is significantly associated with better total factor and labour productivity performance and he further shows that these learning effects are most pronounced among established exporters although they can be insignificant and occasionally negative in new entrants to export markets. Moreover, in a firm-level survey on manufacturing productivity in five East Asian economies, Hallward-Driemeier *et al.* (2002) not only have identified higher productivity post export-market entry but gone one step further to explore the sources and mechanisms of this productivity growth – it is in aiming for export markets that firms consistently make a series of decisions that consequently accelerate their productivity, with regard to their investment, training, technology, selection of inputs, etc. Castellani (2002) also reports a positive relationship between labour productivity and exporting intensity for Italian firms between 1989 and 1994: only firms substantially involved in exporting have

[67] As Crespi *et al.* (*op. cit.*) state "… a possible explanation of why our results in favour of the 'learning-by-exporting' hypothesis might be stronger than those found in most of the previous exporting-productivity studies is that the impact of learning effects might have been hidden by the noise in productivity measures when directly learning measures are not available" (p. 621).

significantly faster productivity growth. More recent empirical testing of the leaning-by-exporting theory has adapted the model by Olley and Pakes (1996) to obtain firm-level estimates of productivity using a production function approach, with productivity (in part) determined by past exporting experience leading to learning effects (*c.f.* Pavcnik, 2002; van Biesebroeck, 2005; Fernandes and Isgut, 2007; De Loecker, 2007). These studies show a strong 'learning-by-exporting' effect for countries like Columbia, Slovenia and several sub-Saharan countries.

What's more, there is also a strand of literature documenting evidence on the co-existence of selection and learning effects. Baldwin and Gu (2003) explore the export-productivity linkage in Canadian manufacturing and find evidence that productivity improves following export-market participation; in contrast to Kraay (1999) they find learning effects of export are stronger for younger businesses. Using data for the UK chemical industry, Greenaway and Yu (2004) test both hypotheses and find strong evidence that firms self-select into export markets; they however also report more varied learning effects dependent on the age of establishments – significant and positive for new entrants, less significant for more experienced exporters and negative for established exporters. More recently, Girma *et al.* (2004) use 'propensity score matching' technique to overcome the problem of selectivity bias, and thus suggest that firms do self-select into export markets but that exporting also further boosts firm-level productivity.

Arguably the evidence still remains inconclusive regarding the causal mechanisms underlying the well-established empirical association between export orientation and productivity growth, in particular whether the 'learning-by-exporting' hypothesis holds. Nevertheless, there may be several explanations to account for such discrepancies in the empirical literature in this area.

To begin with, the fact that finding a 'learning-by-exporting' effect is more elusive, when compared with the impact of pre-entry selection effects, may be explained by differences in country-, industry- or firm-specific characteristics. For instance, Baldwin and Gu (2004) put forward a convincing explanation as to why there should be different learning effects in Canadian and US plants: learning from international best practices is more important for productivity growth in Canadian plants that export vis-à-vis US plants, whose principal source of raising productivity is technology developed domestically. In addition, given a smaller market size in Canada where competition is not as intense as in the US, exposure to international competition is more likely to induce participants to become more productive and competitive. Thirdly, expanding into much larger foreign markets relative to domestic market, Canadian producers will benefit from greater product specialisation and longer production runs, which is more likely to have an impact on productivity; whereas this is less of an issue in US firms given the already bigger domestic market. All of these will contribute to a greater export impact on productivity growth in Canada.

Similar mechanisms of raising productivity may also apply in the UK. For instance, learning benefits are likely to be more pronounced in the UK firms that export vis-à-vis US firms, since the UK firms are overall likely to be more distant to technological frontier (which is set by the US), and they are also exposed to a less competitive domestic market (Girma *et al.*, 2004). In contrast, Sweden has a high participation rate for firms involved in export markets and high degree of openness, which to some extent resembles more the US economy. This may partly explain the similar performance profiles found between Swedish exporters and non-exporters (Greenaway *et al.*, 2003).

In addition to these country-specific differences associated with the learning process, firm performance characteristics may well differ both within and across industries as well. From an RBV perspective, in order to learn when operating in foreign markets, and in order to internalise international knowledge spillovers, a firm needs to invest more in training and innovation so as to enhance its absorptive capability to exploit and assimilate (often tacit) knowledge that is obtained externally. This argument is substantiated by the evidence of significant learning effect uncovered in the UK chemical industry, which is a typical high-tech sector that undertakes a large amount of R&D expenditure (Greenaway and Yu, 2004). Others have found post-entry effects depend on existing industry characteristics, such as the extent of industry exposure to exporting and FDI (higher exposure leading to stronger post-entry productivity effects – Fernades and Isgut, 2007); while Greenaway and Kneller (2007) review the evidence of other studies that have shown that learning is more likely when firms are relatively young and/or highly engaged in exporting activities.

Secondly, the heterogeneity of export markets may also play a role in determining the extent to which participants will gain higher productivity from exporting. For instance, Damijan *et al.* (2005) suggest that learning from exporting is crucially dependent on the degree of competitive pressures facing firms in different foreign markets – exporting *per se* does not warranty productivity gains; rather, productivity only improves significantly when firms are serving advanced, high-wage export markets. Also, De Loecker (2007) confirms that destination is important in Slovenia, with exports to high income countries driving 'learning-by-exporting' productivity effects.

Finally, there are also certain methodological issues involved when testing for productivity effect of exporting. For instance, there are structural differences between the various databases used when testing for learning effects (e.g. how representative the data are of the underlying population of firms). Secondly, potential econometric problems may arise since most empirical studies tend to pool information across all firms with heterogeneous export histories to examine the learning effects of exporting. In fact, distinct learning effects are uncovered amid firms of different age (Kraay, 1999; Delgado *et al.*, 2002; Baldwin and Gu, 2003; Greenaway and Yu, 2004) [68] . Lastly and most importantly, sample selectivity is the problem usually encountered in micro econometric evaluation studies (see Chapter 5, pp. 211-221, for a discussion of the econometrics of the sample-selection issue in detail). In particular, the significance and size of a 'learning-by-exporting' effect seem particularly sensitive to whether any (or what) approach is used to combat the selection problem. This problem arises when making comparisons between a 'treatment group' (e.g. export-market entrants) and the rest of the population, when it is suspected that the treatment group are not drawn randomly from the whole population. This issue is of paramount importance when interpreting the results obtained from comparing exporters and non-exporters, and upon which policy conclusions are then based.

More specifically, participants in export markets may posses certain characteristics such that they achieve better performance (in terms of higher productivity) vis-à-vis non-participants even when they do not enter export

[68] For instance, Krray (1999) allows export history to have an effect on learning effects (by allowing the coefficient on lagged export to vary with the export history of the plant), and finds significantly positive effects of exporting merely in more established Chinese firms.

markets, and this productivity gain is correlated with the decision to participate in global markets. This will mean that standard estimation techniques lead to biased results. These characteristics would likely include superior managerial capability, organisational skills, absorptive capacity, etc. They are associated with both the objective of achieving higher productivity and the decision to self-select into export markets.

That ignoring selectivity problem leads to biased results is indeed reinforced by the theoretical evidence of the heterogeneity in firm productivity prior to entry (Head and Ries, 2003; Melitz, 2003; Helpman *et al.*, 2004) and the unanimous empirical evidence of significant differences between exporters and non-exporters (in terms of productivity, employment, capital-intensity, R&D, etc.), but similar characteristics between new exporters and continuing exporters.

For example, using a propensity score matching approach, Girma *et al.*, (2004) find significantly positive post-entry learning effects for UK exporters. Additionally, in conjunction with matching, Greenaway and Kneller (2004) use a difference-in-difference approach to control for changes in other observable determinants of productivity post entry, and find that there are significant productivity gains from exporting in the unmatched sample but these disappear when they use a matched sample. Other approaches suggested in the literature to deal with self-selection bias include instrumental variable estimation and Heckman two-stage estimation, which are closely linked in a way. For instance, Kneller and Pisu (2007) provide an example of deploying Heckman selection process to model two decisions of whether to export or not and how much to export, but in a different setting − export spillovers from FDI. As far as this thesis is concerned, there are few studies utilising instrumental variable estimation to examine the causality between export and productivity, possibly due to lack of appropriate instruments.

4.2 The Impact of Exporting upon Aggregate Productivity and Reallocations of Resources

Another important channel for exporters' contributing to the economy is through boosting aggregate productivity growth. This is an emerging strand of literature that focuses on the impact of firm-level exporting on inter- or intra- industry reallocations of resources and therefore aggregate productivity growth. This approach provides a holistic view of the interaction of plants, industries and the aggregate economy as a whole.

4.2.1 Export-Market Dynamics

As discussed at the outset of Chapter 2, general empirical findings show that the determinants of a firm's entry decision include trade liberalisation (Baldwin and Gu, 2004), sunk entry costs (Bernard & Jensen 2004a; Girma *et al.*, 2004; Das *et al.*, 2007) and some firm-level characteristics such as size (Aw and Hwang, 1995; Roberts and Tybout, 1997; Bleaney and Wakelin, 2002; Gourley and Seaton, 2004); experience including *ex ante* success (Bernard and Jensen, 1999; Greenaway and Kneller, 2004; Kneller and Pisu, 2007); export spillovers (Aitken *et al.*, 1997; Greenaway *et al.*, 2004); foreign networks (Sjoholm, 2003). A firm's exit decision depends mainly upon industrial characteristics such as the level of sunk costs; the firm will exit once it is not productive enough to secure non-negative profits (Das *et al.*, 2007; Bernard and Jensen, 2004a).

The process of entry and exit in export markets differs from market entry and exit in the conventional sense, since the firm can continue to produce for the domestic market. Baldwin and Gu (2003) find export entry to involve substantial experimentation. They emphasise the importance of an 'entry fee' as an initial investment, which is in line with the general consensus on the importance of sunk costs. Entrants to export markets have to achieve superior performance before they enter and are rewarded with even better performance after they penetrate these foreign markets.

Export-market dynamics have been modelled in recent studies by incorporating intra-industry heterogeneity. In their model, Bernard *et al.* (2003) show that in a setting of Bertrand pricing rules, trade liberalisation expands the market shares of the most productive firms by providing them with large export markets, while at the same time such liberalisation forces firms at the lower end of the productive efficiency distribution to quit as international competition intensifies.

In a slightly different setting, Melitz (2003) develops a forward-looking model of steady-state trade with heterogeneous firms and imperfect competition to show that trade liberalisation increases a country's imports and erodes domestic sales and profits. Firms at the higher end of the productivity distribution expand their export sales more than they contract their domestic sales; whereas those non-exporters at the lowest end of the productivity distribution have to contract or quit. Consequently, freer trade induces aggregate productivity gains, as 'better' firms expand their market shares and the 'worst' firms contract or exit.

Empirically, the effect of transitions into and out of export markets on firm performance is often captured by its export premium, which measures how much a firm's performance changes when its export status changes (Bernard and Jensen, 1999 for the US; Aw *et al.*, 2000 for Korea and Taiwan; Silvente, 2005 for the UK). The studies of the US, Korea, and Taiwan find that when firms switch from being non-exporters to becoming exporters, their performance improves, while switching from being exporters to being domestically-oriented firms retards their performance. In Silvente's study, which covers a sample of UK small firms over a 7-year period, it is also shown that there are symmetric effects on the export premium between entrants and exiters – new exporters enjoy considerable gains while exitors from overseas markets suffer significant losses in terms of employment, wages, sales and productivity growth rates[69].

Bernard and Jensen (2004b, Figure 1) illustrate productivity differentials between distinct sub-groups of firms in US manufacturing. Their Figure 1 of TFP paths of various sub-groups show that new entrants into export markets are rewarded with a surge in TFP especially during the first year post entry, and thereafter their productivity path becomes flatter, following that of continuous

[69] The results from these studies control for the impact of covariates, such as size and industry effects.

exporters (although with significantly lower productivity levels). In contrast, those that exit from exporting are characterised by a substantial deterioration in productivity to eventually resemble the flat growth trajectory of continuous non-exporters. On the whole, firms that always export achieve TFP growth that is 8 to 9 per cent higher than those that never enter export markets. Thus, changing export status is indeed associated with considerable fluctuations in productivity. Nevertheless, these drastic changes in TFP during transition do not seem to persist in the long run. With reference to the 'learning-by-exporting' hypothesis, continuous export behaviour does not appear to lead to more rapid productivity growth; rather, TFP growth slows down.

Similarly, Baldwin and Gu (2003) also point to a negative impact for those that exit: the 'ebb and flow' induced by international competition culls some participants from export markets. The least successful entrants have to withdraw back to domestic markets and then lag further behind those that continue serving foreign markets. That is, productivity growth is lower for quitters than continuers, and substantially lower when compared to new entrants to export markets[70].

4.2.2 Restructuring and Aggregate Productivity Growth

So how does this export-market restructuring impact on aggregate productivity growth? Before addressing this issue, it is important to consider the interaction of firms, industries and aggregate productivity growth. A rapidly growing body of research has sought to provide micro evidence on the role of resource reallocations for productivity growth (*c.f.* Bartelsman and Doms, 2000, for a survey of the literature). Here resource reallocations can comprise intra-firm reallocations (as firms become more efficient over time), inter-firm reallocations (as less efficient firms lose market shares) and entry and exit (assuming that new firms are more productive than those that exit). Some of the representative studies include Baily *et al.* (1992), Olley and Pakes (1996),

[70] In addition, the negative impact of exit on firm efficiency is also captured in Bernard and Wagner (1997) and Clerides *et al.* (1998).

Haltiwanger (1997), Bartelsman and Dhrymes (1998) and Foster *et al.* (2001) for the US; Disney *et al.* (2003) for the UK. These are mostly based on some form of decomposition of an index of industry-level productivity. For instance, Olley and Pakes (1996) examine the dynamics of productivity in the US telecommunication-equipment industry over three decades, and show that since 1975 most of the productivity growth in the industry has increased as a result of reallocations of resources, particularly the high exit probabilities for plants in the lower end of the productivity distribution.

Nevertheless, none of the above-mentioned studies covers the effect of exporting on industrial restructuring and thus aggregate productivity, which has merely started to catch attention in more recent studies, say for the US, UK, Canada and Sweden. This more recently developed literature is reviewed below.

The United States

Motivated by the empirical evidence of the effect of trade on productivity, Melitz (2003) develops a theoretical model, allowing for heterogeneous firms, to study trade, intra-industry reallocations and their impact upon aggregate productivity. In a general equilibrium setting, the model shows how trade liberalisation induces only the more productive firms to participate in export markets whilst simultaneously forcing the least productive ones out of the market. Here the additional sales gained by more efficient firms as well as the exit of the least efficient ones jointly contribute to reallocations of market shares towards the more productive firms and this eventually leads to aggregate productivity gains. In doing so, profits are also equally reallocated towards more productive firms. This model highlights an important transmission channel for understanding the interaction between firms and industry performance, drawing on the notions of sunk entry costs as well as firm-level heterogeneity. Above all, it is crucial to treat firms differently due to the fact that the impact of trade is distributed differently across firms with differentiated levels of productivity. That is, the trade-induced reallocation effect amongst heterogeneous firms generates changes in a country’s aggregate productivity, which cannot be explained by models based on representative firms (as in the conventional neoclassical models).

A more recent development in the theoretical modelling of trade can be found in Bernard *et al.* (2005). In a similar fashion, they show how the interactions of firms, industries and countries can affect the way economies respond to globalisation, again within a general equilibrium setting incorporating monopolistic competition and heterogeneous firms. However, they take a different approach in that they concentrate on comparative advantage. Their model generates a number of novel predictions about the impact of falling trade costs on job turnover, aggregate productivity and the welfare gains obtained through reallocations of resources. First of all, intra- and inter-industry reallocations of resources brought about by trade liberalisation improve average industry productivity and sectoral firm output, but relatively more so in industries with a comparative advantage than in those with comparative disadvantages. Secondly, these trade-induced reallocations also lead to considerable job turnover in all industries, with ultimately net job creation in comparative advantaged industries and net job destruction in comparative disadvantaged ones. Thirdly, the creative destruction of firms taking place in all sectors in the steady state, but this is more highly concentrated in comparative advantage industries vis-à-vis comparative disadvantage ones. Lastly, the productivity gains from creative destruction, which is associated with heterogeneous firms, magnify *ex ante* comparative advantages and therefore constitute a new channel for welfare gains, as trade costs fall.

This model distinguishes itself from that developed by Melitz (2003) principally in that it allows for different results across industries and countries with comparative advantages. For instance, the importance of firm self-selection varies with the complex interactions of country and industry characteristics; and the strength of gross job flows and the extent of steady-state creative destruction all differ across industries and countries.

Lastly, Bernard and Jensen (2004b) provide an empirical study of trade-induced aggregate productivity growth, utilising micro data for US manufacturing. It is shown that foreign exposure does indeed foster productivity growth for firms, industries and manufacturing as a whole. In particular, increased export opportunities are associated with both intra- and inter- industry reallocations (from less efficient plants to more efficient ones), accounting for 40% of TFP growth in the manufacturing sector, half of which is explained by an intra-industry reallocation of economic activities. Thus, the higher productivity levels as well as the faster growth rates found in exporters (in terms of employment and output) offer an additional reallocative channel for explaining aggregate productivity growth. Limitations of this study are that market entry and exit are not considered; and that all plants in the dataset existed throughout the period of study. Thus, there is no comparison of the relative importance of 'creative destruction', and most importantly how trade interacts with market entry and exit.

The United Kingdom

Emerging evidence on industrial restructuring has shown that UK productivity growth is increasingly due to a market selection process, in which more productive entrants replace less productive establishment whilst high productivity incumbents gain market shares (*c.f.* Oulton, 2000; Disney *et al.*, 2003). In particular, the study by Disney *et al.* suggests that between 1980 and 1992, 50% of labour productivity growth and 80-90% TFP growth could be explained by what they term external restructuring effects (i.e. the impact of market entry and exit as well as inter-firm reallocations in market shares). Given the importance of the impact of industry restructuring on productivity growth in the UK, Criscuolo *et al.* (2004) extend Disney *et al.*'s (2003) analysis to cover the UK manufacturing for the 1980-2000 period. Unfortunately, it is not possible to assess the contribution of exporters for the UK, in terms of restructuring effects due to lack of data. The innovative feature of this study is their attempt to explain entry/exit restructuring effects in terms of the contribution of globalisation, and thus how the latter impacts on aggregate productivity growth. They show that the reallocations of resources (through entry and exit) affect aggregate productivity to an increasingly large extent – roughly 25% of productivity growth could be accounted for by this net entry effect from 1980-1985 and this amount went up to around 40% of labour productivity growth from 1995-2000. They then go on to show that globalisation (as measured by sectoral import penetration and the use of ICT) is important in determining the share of net entry in explaining labour productivity growth in UK manufacturing. However, these results suffer from a high level of aggregation and co-linearity problems, precluding any precise estimates of what proportion of aggregate productivity growth is due to import penetration effects.

Other Countries

Finally, a limited amount of micro evidence on trade-induced productivity growth is available for some other countries. For instance, Baldwin and Gu (2003) find exporters accounted for almost 75% of productivity growth in Canadian manufacturing during the 1990s (even with less than 50% employment), 28% of which was accounted for by export-market entry (of both existing and new entrants). Moreover, Falvey *et al.* (2004) also show that exporting has a sizeable effect on industry productivity growth using Swedish manufacturing data, in terms of increasing market shares for higher productivity exporters.

Chapter 5: An Empirical Analysis of the Exporting-Productivity Nexus at the Firm Level

The literature reviewed in Chapter 4 suggests a number of ways in which exporting, the successful exploitation of overseas markets, can contribute to the firm's performance at the micro level. In particular, firms that start exporting have to overcome barriers to international markets (i.e. sunk entry cost), and therefore invest in resources and capabilities that provide them with the ability to compete effectively in overseas markets (i.e. absorptive capacity). Thus they achieve higher productivity levels as a prelude to exporting; consequently, there is a self-selection process whereby enterprises that enter export markets do so because they have higher productivity prior to entry (relative to non-entrants). This also raises the issue of whether exporting itself leads to further benefits through 'learning-by-exporting'. The empirical evidence (as reviewed in Chapter 4) provides significant support for the 'self-selection' hypothesis but much less support for the 'learning-by exporting' hypothesis.

It is worth noting that although this thesis concentrates on the productivity-exporting linkage at the micro level, undoubtedly, it also needs to acknowledge another equally important (if not more) channel for exporting to contribute to productivity growth at the aggregate level. Indeed, irrespective of whether firms self-select into international markets and/or become more productive post-entry, dynamic restructuring of the economy (including growth of firms and entry/exit) results in larger market shares for the most efficient (and usually larger) firms that export, and this has a sizeable impact on boosting aggregate productivity. There is growing evidence (both theoretical and, to a more limited extent, empirical) that internationalisation has a positive impact on aggregate productivity growth. In a recently published study using the *FAME* data, Harris and Li (2008) have, for the first time for the UK, decomposed the aggregate productivity growth and documented a considerable contribution of exporting (in terms of dynamic competition effects, entry and exit and within firm productivity growth) to national productivity. It follows that the aggregate impact of exporting is no longer the focus of this thesis.

The contribution of exporting to productivity growth is important for policy. For instance, substantial evidence of the benefits from international trade provides the UK government with a rationale for intervention to help firms develop their exporting activities when there are market failures (DTI, 2006). These benefits are largely linked to the higher productivity of exporters, which then contribute to overall UK productivity growth through various channels, such as the entry of higher productivity exporters (e.g. the 'born-global' companies as discussed in Chapter 1, pp.22-26); existing exporters becoming more productive over time and/or intra-industry and inter-industry resources being reallocated to higher productivity exporters; and the shutdown of lower productivity firms − both exporters and more likely non-exporters with the lowest productivity level, as predicted by some recent theoretical models (Bernard *et al.*, 2003; Melitz, 2003). These different channels through which exporters can affect (productivity) growth are likely to call for different policy responses from the government, if some are more important than others. For example, if existing exporters achieve higher productivity prior to exporting, with little further gains post-entry, then policymakers might want to target support to potential rather than actual exporters (Greenaway and Kneller, 2007), and/or ensure that policies do not hinder market processes both through intra-firm reallocations and market entry and exit (Hoekman and Javorcik, 2004).

There has to date been little micro-based evidence for the UK that quantifies the importance and contribution of exporting to overall UK productivity growth, although Harris and Li (2008) have recently decomposed productivity growth in the UK to show that exporters do indeed experience faster productivity growth than non-exporting firms and therefore contribute more to national productivity growth. More importantly, as far as the present analysis is concerned, there have only been a limited number of econometric studies for the UK that have considered both whether exporters are 'better' than non-exporters, and whether there is any post-entry productivity improvement to exporters (e.g. Girma *et al.*, 2004; Greenaway and Kneller, 2004; Greenaway and Yu, 2004). These analyses have used data from the *FAME* and *OneSource* databases based on returns firms have to make to Companies House in the UK, but there are a number of issues that arise from the use of these data, for example, the limited coverage of manufacturing sector only, and that the samples used in statistical analysis are not representative of the UK population of firms and as a result large firms are over-sampled[71].

Thus a major aim of this chapter is to use (where possible) appropriate data sources from the *ARD* and *FAME* to shed light on the following issues:

- to quantify the extent to which exporters have higher TFP, when compared to non-exporters. As all other analyses undertaken in this chapter, this initial analysis takes into account firms in all market-based sectors (instead of manufacturing only as in most other work on this topic), paying special attention to the diverse patterns of productivity in distinct industry sectors;

- to assess the extent to which productivity growth within firms may be stimulated by exporting, through organisational learning, economies of scale, etc. In terms of structural dimensions, this part includes investigation of possible productivity effects of learning which may occur as a result of preparation for entering overseas markets, as well as looking at productivity effects which may occur following overseas market entry, and effects on medium to longer term productivity trajectories.

5.1 The Construction of a Weighted FAME Dataset

5.1.1 The Original FAME Dataset

The *Financial Analysis Made Easy* (henceforth *FAME*) dataset, collected by Bureau van Dijk Electronic Publishing (BvDEP), is used for this analysis of the exporting-productivity relationship. The *FAME* provides the most comprehensive firm-level data for the UK that contain information on exports as well as other firm-specific characteristics, such as turnover, intermediate expenditure, employment, tangible and intangible assets and so on. The *FAME* data source includes all firms operating in the UK that are required to make a return to Companies House and thus provides observations from every sector of the

[71] These issues will be revisited as this chapter develops.

market-based economy. Apart from financial information, *FAME* also has information on the year of incorporation of the company, postcodes, the 4-digit 2003 SIC industry code and country of ownership[72].

The original dataset contains almost 8 million observations, and if only those with information on overseas turnover are included, the number of observations reduces to 854,397. Further omitting observations with missing information on employment, intermediate expenditure, or (tangible/intangible) assets, and limiting the data period to just 1996-2004[73], the dataset reduces to 346,911 observations. Moreover, SIC codes are also used as a criterion of inclusion of records: observations are omitted if they fall in non-trading industries (i.e. SIC 7499), private households (i.e. SIC above 930) or if their SIC codes are missing. Lastly, only data containing unconsolidated accounts are included, to avoid the effects of double counting and within firm transfer. Therefore, the final dataset used for statistical analysis comprises of an unbalanced panel, containing 81,819 firms with 326,906 observations covering 1996-2004, where information on 'entry and exits' into export markets is also available. The analysis below reveals that around 23% of firms are observed throughout the nine-year period; thus the majority of firms are observed for only some of 1996-2004.

[72] More detailed information of the *FAME* can be found on BvDEP's website at http://www.bvdep.com/en/index.html

[73] Data for 2005-06 are omitted because there is a substantial fall in the number of observations for these years that mostly reflects firms not having yet submitted their company accounts (or not having yet reached the *FAME* dataset). Similarly, the number of observations before 1996 also falls significantly, so these data are omitted too. Additionally, a small number of duplicate cases are also removed.

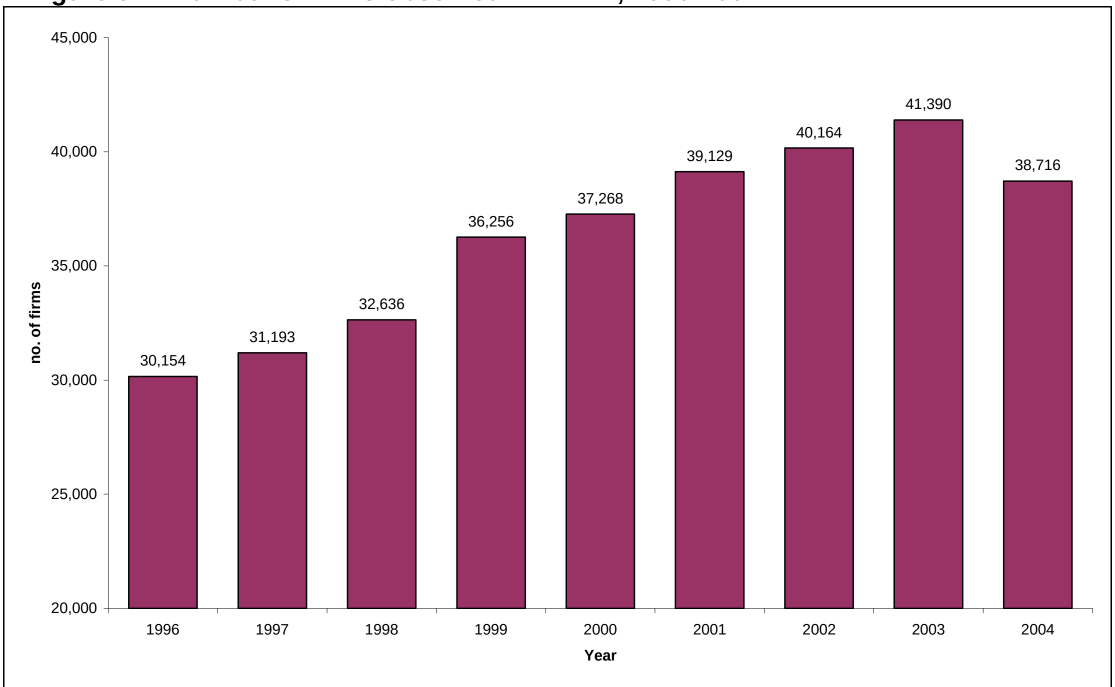
Table 5-1: Some descriptive statistics

	Mean	Minimum	Maximum	Std. Dev.
Year of accounts	2000	1996	2004	2.5
Total turnover (£'000)	45,638	-2,030	152,617,000	620,902
Overseas turnover (£'000)	12,118	0	124,418,000	436,999
Total intermediate expenditure (£'000)	43,349	-19,345	142,313,000	581,931
Employment	362	1	412,574	3,329
Tangible assets (£'000)	18,239	0	54,747,000	319,688
Intangible assets (£'000)	4,188	-319,000	108,839,000	214,846
Year of incorporation	1980	1856	2005	20.7
No. of observations- 326,906				

Source: unweighted *FAME* database.

Table 5-1 provides information on the key variables in the *FAME* dataset to provide some intuition on these data. Here turnover, intermediate expenditure on bought-in goods, services, materials, etc., employment and assets would be needed for the calculation of TFP in subsequent statistical analysis using a production function approach. The information on the year of incorporation of the company is vital to understanding the (exporting) status of the firm in the analysis regarding market dynamics.

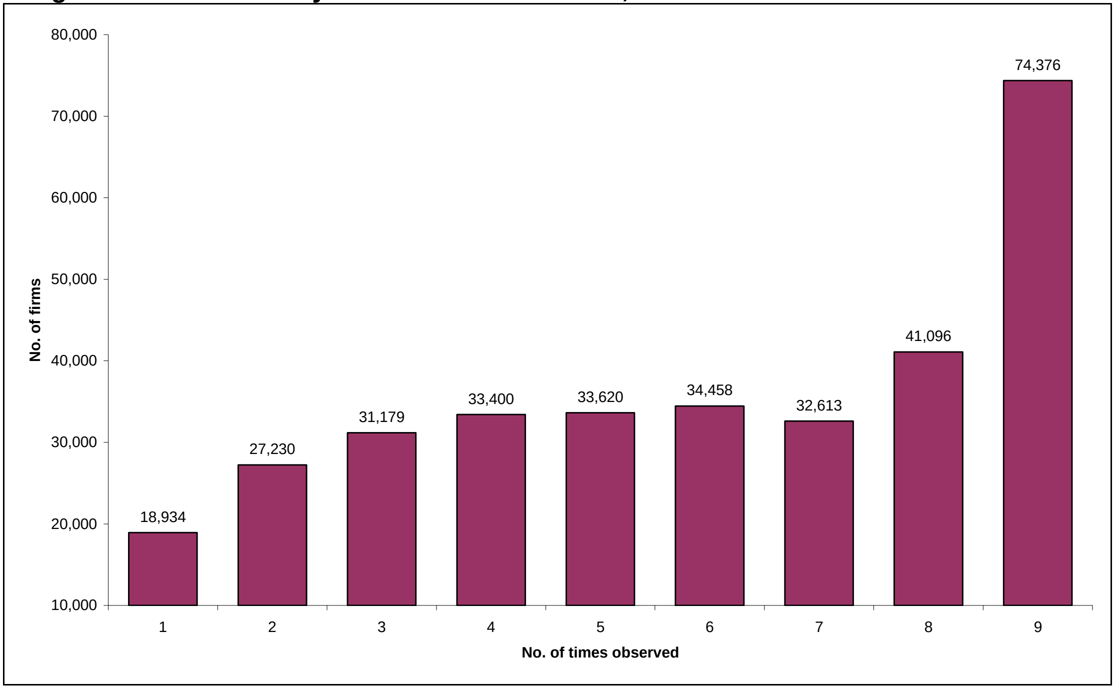
Figure 5-1: Number of firms observed in *FAME*, 1996-2004



Source: unweighted *FAME* database

In terms of the panel aspects of the *FAME* database, Figure 5-1 above shows how many enterprises are represented in each year, uniquely identified by their CRN codes (i.e. Company Registration Number). This is an unbalanced panel (linked over time by CRN codes), given that there are different numbers of observations in each of the nine years, Figure 5-2 below further shows that nearly 23% of firms (with unique CRNs) are observed in all nine years; thus the majority of firms are observed for only some of 1996-2004, indicating that information is available on 'entry and exits'[74].

Figure 5-2: Number of years observed in *FAME*, 1996-2004



Source: unweighted *FAME* database

To understand in more detail the type of entry and exit underlying the *FAME* data, Table 5-2 shows that the majority of observations are for firms that are first observed post 1996 (i.e. the beginning of data period) and last observed prior to 2004 (the end of data period). Overall, only 102,176 firms (covering just over 31% of the database) are first observed in 1996 and last observed in 2004. The remainder therefore can be classed as those that enter and those that exit, but the reasons for this are not synonymous with opening and closure (or 'birth' and 'death') of firms.

[74] Note also, a significant number of firms 'exist' throughout 1996-2004 (or various sub-periods) but do not provide information for every year. As an example, Table 5-2 shows that 102,176 firms existed throughout, but Figure 5-2 shows that only 74,376 of these provided 9 years of data.

Table 5-2: 'Entry and exit' in the *FAME* database

Year first observed	Year last observed									
	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
1996	3628	5582	6698	7451	7635	8923	10184	16684	102176	168961
1997	–	1233	1336	1592	1831	1801	1977	3498	18129	31397
1998	–	–	1324	1500	1608	1907	1942	3242	15389	26912
1999	–	–	–	1930	1920	2449	2400	3851	17442	29992
2000	–	–	–	–	1371	1620	1894	3254	14302	22441
2001	–	–	–	–	–	1389	1556	2914	12656	18515
2002	–	–	–	–	–	–	1388	2526	10109	14023
2003	–	–	–	–	–	–	–	1961	7994	9955
2004	–	–	–	–	–	–	–	–	4710	4710
Total	3628	6815	9358	12473	14365	18089	21341	37930	202907	326906

Source: unweighted *FAME* database

5.1.2 Constructing a Weighted FAME Dataset Using the ARD

The *FAME* dataset is severely biased towards large enterprises, and thus is unrepresentative of the population of UK firms for any results/conclusions to be generalised to the UK level. This 'over-representation' can occur for a number of reasons. For instance, there are differences in how firms are classified to industries between the *ARD* and *FAME* – *FAME* has better coverage of some sectors which are not well represented in the *ARD* (e.g. some areas of business services); there may be some bias towards larger firms in *FAME* with consolidated and unconsolidated returns (i.e. smaller companies have their accounts grouped with other companies, placing them in a larger size group).

Table 5-3: Ratio of employment in *FAME* to *ARD* for each industry by size-band

Industrial sectors	Small (<13)	Medium (13-66)	Large (>66)	All
Agriculture, fishing, forestry	18.3	104.2	38.3	38.5
Mining & quarrying, food, textiles, clothing	1.7	12.9	90.0	79.4
Wood, paper, minerals, metals etc	1.6	16.2	102.2	77.5
Machinery, transport equipment	1.9	23.0	129.6	103.7
Utilities & construction	0.8	15.0	50.6	38.0
Distribution, hotels, catering	0.7	12.0	144.0	84.1
Transport, communication	4.8	27.0	215.0	148.2
Other Business services	2.1	19.8	140.3	76.4
Education, health	0.6	2.7	32.3	21.2
Other services	1.5	14.6	190.1	60.3
All sectors	1.5	14.8	109.2	72.7

Notes: figures are percentages.
Source: *ARD* and *FAME* databases

For instance, to illustrate the problem faced, each cell in Table 5-3 represents the ratio of average total employment in *FAME* to the average from the full *ARD*, broken-down into 3 enterprise size-bands and by 1-digit industry groups. These figures confirm that data in *FAME* are significantly biased towards coverage of larger firms; indeed, in some industries *FAME* has a larger employment total than the *ARD* (e.g. *machinery*, *transport equipment*; *transport*, *communication*).

Table 5-4: Distribution of employment across industries by size-bands

Industrial sectors	Small (<13)		Medium (13-66)		Large (>66)	
	FAME	*ARD*	*FAME*	*ARD*	*FAME*	*ARD*
Agriculture, fishing, forestry	0.8	1.7	2.2	0.8	97.0	97.5
Mining & quarrying, food, textiles, clothing	0.1	4.3	1.4	8.8	98.5	86.9
Wood, paper, minerals, metals etc	0.2	10.4	3.4	16.5	96.4	73.1
Machinery, transport equipment	0.2	9.4	2.9	13.1	96.9	77.5
Utilities & construction	0.4	18.3	3.8	9.6	95.8	72.1
Distribution, hotels, catering	0.2	27.1	2.3	16.0	97.5	56.9
Transport, communication	0.6	18.5	2.7	14.9	96.7	66.7
Other Business services	0.9	31.2	4.5	17.3	94.7	51.5
Education, health	0.3	10.5	3.4	26.4	96.3	63.1
Other services	1.2	47.6	5.5	22.8	93.3	29.6
All sectors	0.4	20.6	3.1	15.1	96.5	64.3

Notes: figures are percentages of industry totals.
Source: *ARD* and *FAME* databases.

Table 5-4 provides similar information, but instead of ratios, it shows the percentage of total employment in each industry that is attributed to the 3 different firm size-bands. Overall, the *FAME* data has only 0.4% of all employment in the smallest firms, whereas the *ARD* has some 20.6%. Similarly, *FAME* has only just over 3% of all employment in medium-sized firms, whereas the *ARD* has over 15%. In contrast, the largest firms (employing over 66) account for more than 96% of total employment in *FAME* compared to just over 64% in the *ARD*.

Therefore, above all, a primary issue to be addressed before any empirical analysis is to construct a valid dataset to obtain a distribution representative of the population of firms operating in the UK, and thus allow a comprehensive evaluation of contribution of all UK exporters. Hence the starting point for this chapter is the merging of the *FAME* dataset into the nationally representative *ARD* data, in order to bring a variable on ‘overseas turnover’ from *FAME* into the *ARD*. Nevertheless, this attempt to merge *FAME* *i*nto the *ARD* is largely unsuccessful, as the matching rate is unsatisfactorily low and the resulting merged dataset is still biased towards large/medium firms.

Clearly, the use of a free-standing *FAME* database would have many more observations compared with the matched *FAME-ARD* data. Subsequently, an alternative approach is carried out where the firms in the *FAME* dataset are treated as a sample of the *ARD* population, and consequently weighted to produce a representative database (by industry and firm size). In practice, aggregated turnover data are derived from the 2003 *ARD* sub-divided into 5 size-bands (based on turnover quintiles[75]) and 3-digit industry SICs (the result is 757 sub-groups).

The *FAME* data are then aggregated into the same sub-groups, so as to allow weights to be calculated using the total turnover data from the *ARD* divided by the comparable data from *FAME*. In essence, the *FAME* data are being used as a sample of the *ARD*, and weighted accordingly to ensure that they acquire the same distribution of turnover (across size-bands by industry) as those firms in the *ARD*.

There are a few exceptions to this weighting exercise. First of all, where there are fewer than 10 enterprises in any sub-group in the *ARD*, these data are not used, so as to comply with rules of the ONS on disclosure of confidential information. This results in a loss of some 4% of the total turnover available in the *ARD*. Secondly, the *FAME* data for 34 industries are not weighted, because in these cases the *FAME* data have better coverage in terms of total turnover than the *ARD*, or the data did not match the *ARD* data by size-band within the industry. These 34 industries (out of 215 in total) account for just 2.9% of total *FAME* turnover. Lastly, the *ARD* does not contain data for Northern Ireland but since this region is rather small it will not have much of an effect in the weights used.

[75] Note, these are based on dividing the *FAME* data into 5 equally sized groups based on turnover data, in order to obtain the cut-off points for each size-band.

Table 5-5: GB turnover (£m) in 2003 based on *FAME* and *ARD* by turnover-bands

	FAME				*ARD*		Weighted *FAME*/ *ARD*
Turnover-band	Unweighted	%	Weighted	%		%	%
	(1)		(2)		(3)		[(2) ÷ (3)] x100
<44	26.9	0.0	460.1	0.0	509.7	0.0	90.0
44 - 227	380.7	0.0	7,969.6	0.7	8,509.4	0.8	93.5
228 - 1184	3,578.5	0.2	60,892.8	5.3	63,751.8	5.9	95.5
1185 - 7244	49,683.9	2.4	198,417.1	17.4	200,988.3	18.5	98.7
>7244	1,988,609.3	97.4	874,543.9	76.5	812,157.0	74.8	107.5
All	2,042,279.4	100.0	1,142,283.4	100.0	1,085,916.2	100.0	105.0

Source: *ARD* and *FAME* databases.

Table 5-5 presents the results from weighting the *FAME* data. The unweighted data from *FAME* are dominated by the largest firms (defined as firms with turnover of £7.2 million or above) since this sub-group accounts for over 97% of total turnover. Weighting the *FAME* produces a distribution across size-bands that is comparable to that obtained when using the *ARD*. This is confirmed in the final column in Table 5-5, which shows that the ratio of *FAME* to *ARD* turnover by size-band is within a margin of ±10%. There is a suggestion that even weighted, the *FAME* data slightly underestimates the contribution of the smallest firms (and correspondingly overestimates the importance of the largest firms), but these differences are not likely to unduly impact on any statistical analysis undertaken using these weighted data.

Table 5-6 produces comparable information but for 1-digit industries. Again the distribution of weighted *FAME* turnover across industries is very similar to that obtained using the *ARD*, whereas unweighted *FAME* data is biased with regard to certain industries (e.g. *wood, etc.*; *distribution etc.*; and *education & health*).

Table 5-6: GB turnover (£m) in 2003 based on *FAME* and *ARD* by 1-digit SIC92

Industrial sectors	*FAME*						Weighted *FAME*/ *ARD*
	Unweighted	%	Weighted	%	*ARD*	%	%
	(1)		(2)		(3)		[(2)÷ (3)] x100
Agriculture, fishing, forestry	7,097.6	0.3	7,550.9	0.7	2,391.0	0.2	315.8
Mining, food, textiles, etc	150,569.8	7.4	52,735.7	4.6	50,776.3	4.7	103.9
Wood, paper, metals etc	362,560.5	17.8	103,360.7	9.0	103,112.0	9.5	100.2
Machinery, transport	136,542.0	6.7	58,231.9	5.1	56,814.9	5.2	102.5
Utilities & construction	186,163.1	9.1	92,124.4	8.1	91,982.5	8.5	100.2
Distribution, hotels, catering	608,086.5	29.8	442,488.9	38.7	442,759.6	40.8	99.9
Transport, communication	198,768.1	9.7	134,655.2	11.8	88,216.8	8.1	152.6
Other Business services	312,059.8	15.3	168,624.7	14.8	167,008.3	15.4	101.0
Education, health	11,542.1	0.6	33,380.6	2.9	33,383.0	3.1	100.0
Other services	68,890.0	3.4	49,130.2	4.3	49,471.8	4.6	99.3
All	2,042,279.4	100.0	1,142,283.4	100.0	1,085,916.2	100.0	105.2

Notes: Unweighted *FAME* data covers the UK.
Source: *ARD* and *FAME* databases

Given the results presented in this section, a good case can be made for using weighted *FAME* data in any statistical analysis, using detailed information on turnover obtained from the *ARD.* All the subsequent statistical analyses are based on this weighted *FAME* dataset. Definitions of variables included in the subsequent analysis are provided in the table below.

Table 5-7: Variable definitions used in the empirical analysis

Variable	Definitions
Firm characteristics	
Export	Dummy variable coded 1 if the firm has positive overseas turnover in any year during 1996-2004
EXP_always	Dummy variable coded 1 if the firm always exported throughout 1996-2004
EXP_never	Dummy variable coded 1 if the firm never exported throughout 1996-2004
EXP_entry[a]	Dummy variable coded 1 if the firm entered into exporting during 1996-2004
EXP_exit[a]	Dummy variable coded 1 if the firm exited exporting during 1996-2004
EXP_both[a]	Dummy variable coded 1 if the firm started and then stopped exporting more than once during 1996-2004
Gross output	Turnover (in £'000 2000 prices)
Intermediate inputs	Cost of sales minus remuneration (in £'000 2000 prices)
Capital stock	Tangible assets (in £'000 2000 prices)
Intangible assets	Non-monetary assets (e.g. innovation, goodwill, brand, etc.) coded 1 if greater than zero; 0 otherwise
Labour productivity	Gross output per employee
Age	Age of the firm in years
Employment	Number of employees in the firm
Industry	3-digit industry (SIC2003)
Region	Standard Government Office regions based on postcodes information in *FAME*
Industry-group variables[b]	
Import penetration	Average import penetration 1996-2004[c]
Export intensity	Overseas sales as a proportion of total gross output
Herfindahl index	Summed of firm shares of industry output squared
Intangible assets	proportion of firms with positive intangible assets

Notes: [a] These variables are coded 1 in year *t* when the firm exports (otherwise coded 0 when it does not export in *t*); [b] Averages for each industry sub-group across time, based on weighting each variable by firm shares in total industry output, and then summing to get the industry figure; [c] These are based on Table 3.6 in 2006 UK Input-Output Tables (ONS, 2006).

5.2 Deriving and Analyzing Productivity

5.2.1 Measuring Productivity

Subsequent empirical investigation requires the use of TFP in testing the export-productivity linkage, thus this preceding section deals with the measurement of TFP. Starting with a standard production function approach such as –

$$y_{it} = \alpha_0 + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_T t + \varepsilon_{it} \tag{5.1}$$

y, *e*, *m* and *k* refer to the logarithms of real gross output, employment, intermediate inputs and capital stock in firm *i* at time *t*. In order to calculate TFP, estimates of the elasticities of output with respect to inputs (i.e. α_E, α_M and α_K) need to be obtained using either a growth accounting or production function approach (see below) and then TFP is measured as the level of output that is not attributable to factor inputs (employment, intermediate inputs and capital). Rather TFP measures the contribution to output of all other influences, capturing such determinants as technological progress and/or changes in efficiency (where the latter also captures the under-utilising of factor inputs unless this is taken into account when measuring these inputs). Thus, such a measure of TFP is equivalent to a combination of the residual ε_{it} from Equation (5.1) and the time trend *t*, which represents technological change. Hence, TFP is obtained from estimating –

$$lnT\hat{F}P_{it} \equiv y_{it} - \hat{\alpha}_E e_{it} - \hat{\alpha}_M m_{it} - \hat{\alpha}_K k_{it} = \hat{\alpha}_0 + \hat{\alpha}_T t + \hat{\varepsilon}_{it} \tag{5.2}$$

Note, totally differentiating Equation (5.1) with respect to time to obtain rates of change (and expressing terms such as dy/dt as $\dot{y}$), omitting sub-scripts and rearranging terms results in an equivalent measure of TFP growth[76] –

$$lnT\dot{F}P = \hat{\alpha}_T \equiv \dot{y} - \hat{\alpha}_E \dot{e} - \hat{\alpha}_M \dot{m} - \hat{\alpha}_K \dot{k} \tag{5.3}$$

In terms of labour productivity growth, a relationship can be obtained by subtracting the logarithm of employment from both sides of (5.1) and expressing the result in terms of rates of change with respect to time (again omitting sub-scripts) –

$$\dot{y} - \dot{e} = (\hat{\alpha}_E - 1)\dot{e} + \hat{\alpha}_M \dot{m} + \hat{\alpha}_K \dot{k} + lnT\dot{F}P \tag{5.4}$$

This equation also sheds light on the major reason for TFP being preferred to labour productivity, as it does not depend on factor substitution. To illustrate this further, increases in labour productivity $(\dot{y} - \dot{e})$ are negatively related to increases in employment [since $(\alpha_E - 1) < 0$], and positively related to increases in intermediate inputs, capital stock and TFP. Indeed, if over time there is an increase in capital deepening (*cet. par*. The k/e ratio rises as capital is substituted for labour perhaps due to greater automation) or outsourcing (*cet. par*. the m/e ratio rises as less is made internally and more semi-finished, finished products and services, are bought from suppliers), then labour

[76] Note, both the constant and the 'error term' are removed from Equation (5.3); the constant, because it is fixed over time; the error term because it is assumed to be random with a mean value of zero. However, in reality, any omitted variables (or errors in measurement) in (5.1) will be systematically picked-up in $\hat{e}_{it}$ and incorporated into the measure of TFP change represented (5.3).

productivity will increase as relatively less labour is used to produce output[77]. Thus, increases in labour productivity do not depend on just technological progress and/or gains in efficiency, since what happens with the other factors of production is also important.

The usual approach to obtaining estimates of α_E, α_M and α_K in Equation (5.1) is not to estimate the production function but to use cost shares in total revenue for each factor input (i.e. the ratio of the cost of each input – such as the total wage bill – to total revenue). That is, if it is assumed that firms price goods at marginal cost, and factors are also paid at their marginal costs, then it can be shown that –

$$\alpha_x = \frac{p_x X}{p_Y Y}; \qquad x = E, M, K \qquad \alpha_K = 1 - \alpha_M - \alpha_E \tag{5.5}$$

The major difficulty with this approach is that, the underlying assumption that the sum of factor input shares in total revenue generated equals 1 (i.e. the so-called 'adding-up' condition) – which is only consistent with constant returns-to-scale technology and perfect competition in factor and output markets – is unlikely to hold for most industries.

In the growth accounting approach, if imperfect competition is allowed (such that total revenues exceed total costs, and price is higher than marginal cost), then it is possible to obtain values for output-elasticities using a cost-based approach –

$$\alpha'_x = \frac{p_x X}{\sum p_x X}; \qquad x = E, M, K \qquad \alpha'_K = 1 - \alpha'_M - \alpha'_E$$

[77] If a value-added production function were used instead of a gross output function (with VA=Y–M), and constant returns-to-scale imposed with perfect competition in factor and output markets, then (5.4) simplifies to

$$\dot{y} - \dot{e} = (1 - \hat{\alpha}_E)(\dot{k} - \dot{e}) + ln\dot{TFP}$$

which shows that labour productivity growth depends positively on capital deepening and TFP growth.

(5.6)

But data on capital costs (the 'user' cost of capital) are now needed and this is not as generally available as other variables. The 'user' cost of capital services in its simplest form is given by –

$$p_K = q_K(r + \delta - \dot{q}_K)$$

(5.7)

where q_K is the price of investment goods; *r* is the rate of return to the capital stock (which in a perfect capital market is equal to 'the' rate of interest); and δ measures economic depreciation (due to obsolescence and 'wear-and-tear'). There are usually problems with obtaining accurate information on the rate of return for different firms and/or industries (see Ellis and Price, 2003 and Wallis, 2005, for the approach taken by Bank of England and the ONS), and Equation (5.7) also ignores the tax structure in operation which can have an important impact on the value of the 'user cost' (see Harris, 1985, for an extensive discussion of these issues).

The assumption of constant returns-to-scale has been shown not to hold for UK manufacturing industries during 1974-1994 by Harris (1999). Estimates of returns-to-scale can also be obtained as a by-product when estimating the 'learning-by-exporting' model below, and again there is strong evidence of increasing returns (IRTS).

The growth accounting approach can be amended to allow for IRTS. As Hall (1986) and Bean and Symons (1989) show, if returns-to-scale γ > 1, then TFP growth can be re-defined as[78] –

$$T\dot{F}P = \hat{\alpha}_T = \dot{y} - \hat{\gamma}(\hat{\alpha}'_E \dot{e} - \hat{\alpha}'_M \dot{m} - \hat{\alpha}'_K \dot{k})$$

(5.8)

However, a prior estimate of γ is required in order to use Equation (5.8), which is typically obtained from econometric estimation of a production function or information on the mark-up of price above marginal cost[79].

[78] See for example of this approach in Harris and Trainor (1997).

[79] The mark-up of price above average cost is often available, but this is not the same as P > MC.

In contrast, the production function approach to measuring TFP can be based on the following augmented model –

$$y_t = \alpha_0 + \alpha_E e_t + \alpha_M m_t + \alpha_K k_t + \alpha_T t + \gamma X_t + \varepsilon_t \tag{5.9}$$

which is equivalent to Equation (5.1) except that a vector of variables, X, has been included, which determine TFP, to try to ensure that estimates of TFP are not biased because of omitted variables (see below)[80].

Note, a more general and flexible function form of the production function can be used to replace the Cobb-Douglas specification used in (5.9) – for example, a log-linear translog function could be used that allows the elasticities of substitution between factor inputs and scale to change with output and factor proportions[81]. There is also an issue about the likely endogeneity of inputs and outputs in (5.9) – given that profit maximisation is usually assumed when specifying this model. Therefore, in practice, an estimation approach is needed such that it takes account of simultaneity (such as using an instrumental variables estimator). There are also econometric issues when using panel data, and the need to take account of fixed effects. However, recent advances in econometrics (such as the systems panel GMM estimator by Arellano and Bond, 1998) mean that in principle it is often possible to tackle the econometric issues associated with using a production function approach to estimating TFP.

A major strength of the growth accounting approach (vis-à-vis the productivity measurement) lies in its straightforwardness: it readily identifies the relative importance of different proximate sources of growth. Nevertheless, this method *per se* proves inadequate if one wants to explore the underlying causes of growth, e.g. innovation and productivity change (*c.f.* OECD, 2001, par. 2.5.1). Thus a problem arises when using either the growth accounting approach, or estimating Equation (5.1) to obtain output-elasticities, and then using these to

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80 Hence TFP in this instance is defined as $ln\dot{TFP} = \hat{\alpha}_T + \hat{\gamma}\dot{X} \equiv \dot{y} - \hat{\alpha}_E \dot{e} - \hat{\alpha}_M \dot{m} - \hat{\alpha}_K \dot{k}$

81 Note, the growth accounting approach is generally implemented using a Tornqvist index number approach, which Caves *et al.* (1982a,b) have shown can be derived from a fully-flexible translog function, although for growth accounting purposes the imposition of CRTS and marginal cost pricing ensures that the translog cross-product terms are all zero and the outcome is equivalent to a Cobb-Douglas specification. Note, however, that the production function approach generally imposes the restriction that $\hat{\alpha}_i$ is constant over time, whereas the growth accounting approach allows these to change from period-to-period.

obtain TFP using (5.2). More specifically, in empirical studies that seek to understand what causes differences in TFP, the determinants of TFP would then need to be modelled – the estimates from Equation (5.2), which do not feature when obtaining the output-elasticities underlying Equation (5.1) and yet which clearly are not random (even though in the production function approach they are captured in the random term ε_{it} in Equation (5.1), where ε_{it} ~ n.i.d (0, σ^2) is required for efficient and unbiased estimation of the model)[82].

It can be shown that using $ln\hat{TFP}_{it}$ based on Equation (5.2) in a second-stage model results in both i) inefficient estimates (potentially inconsistent standard errors and hence inconsistent *t*-values) of the determinants of TFP, due to a two-stage approach being used (Newey and McFadden, 1999, Section 6); and ii) potentially biased estimates since by omitting factors from Equation (5.1) that determine output, the estimates of the $\hat{\alpha}_i$ will suffer from an omitted variable problem and thus $ln\hat{TFP}_{it}$ is incorrectly measured (Wang and Schmidt, 2002). In general, two-stage approaches are inefficient because they ignore any cross-equation restrictions; but even if there are no cross-equation restrictions, such an approach does not take account of the correlation of error terms across equations[83].

The more serious problem is the omitted variable problem. The first-step (i.e. Equation (5.1)) ignores other known determinants of output (which are subsequently shown to be statistically significant); here standard econometric theory points out that the estimates of $\hat{\alpha}_i$ (and thus TFP) will be biased by such an omission[84]. Moreover, the estimates obtained in the second-stage regression will also be biased downward (see Wang and Schmidt, *op. cit.*, Section 2.3, for an explanation). This holds regardless of whether factor inputs and those variables that determine TFP are correlated. Wang and Schmidt (*op. cit.*) show

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[82] The major reason why the two-stage approach has been popular in the literature is that estimates of the $\hat{\alpha}_i$ are often not obtained from estimating Equation (5.1) but rather from using the growth accounting approach based on cost shares.

[83] Since TFP is likely to be endogenous, clearly on this front alone the error terms between Stage 1 and 2 are correlated.

[84] Bias will be negligible only if the two sets of determinants of output (i.e. factor inputs and those variables that determine TFP) are uncorrelated. Since both sets of factors are firm specific, they are likely to be highly correlated.

that in the case of two-step estimators of technical efficiency using the stochastic frontier production function approach, simulations indicate that bias due to the omitted variable problem is substantial. Needless to say their results extend to the present discussion of two-step estimation of the determinants of TFP.

Therefore if the problem under consideration is to examine the causes of TFP (for instance, the role of exporting), the preferred approach is arguably to directly include the determinants of output (and thus TFP) into Equation (5.1), since this avoids any problems of inefficiency and bias, and also allows one to directly test whether such determinants are statistically significant. Put another way, since TFP is defined as any change in output not due to changes in factor inputs, these determinants should be included directly into Equation (5.1), leading to Equation (5.9).

Table 5-8 shows the industry sub-groups (and their code names used) that are used in modelling the links between TFP and exporting. Mean values (weighted by *ARD* weights) are set out for the key variables used in estimating production functions for each industry (see Table 5-7 for definitions of these variables). Gross output is defines as sales in the *FAME* database; these data are deflated using 2-digit deflators available from the ONS for producer price outputs indices (2000 prices)[85].

[85] All price indices are taken from the ONS website (time series database).

Table 5-8: Average values for certain characteristics of domestically-owned firms, by industry sub-group, UK 1996-2004

Industry Group	Industry code	*ln* gross output[a]	*ln* intermediate inputs[a] (*ln* M)	*ln* tangible assets[a] (*ln* K)	*ln* employ-ment[b] (*ln* E)	intangible assets > 0[c]	*ln* age
Agriculture/Forestry/Fish	**AGF**	6.599	6.157	5.750	2.606	0.136	2.
Food/Beverages/Tobacco	**FBT**	5.925	5.712	4.912	2.813	0.283	2.
Textiles/Cloth/Leather	**TCL**	7.268	6.898	4.982	3.350	0.087	2.
Wood products, Paper/Printing	**WPP**	7.017	6.583	4.922	2.893	0.139	2.
Coke/Chemicals, Rubber/Plastics	**CRR**	8.097	7.732	6.552	3.773	0.179	2.
Non-metal minerals, Basic metals/fabricated, Fabricated metals	**MET**	7.003	6.603	5.097	2.995	0.119	2.
Machinery/Equipment; Office equip/Radio, TV; Electrical machinery; Medical/Precision; Motor vehicles/parts; Other transport	**ENG**	7.722	7.349	5.523	3.468	0.179	2.
Manufacturing n.e.c.	**OMF**	6.872	6.469	4.785	2.945	0.145	2.
Construction	**CON**	6.386	5.967	3.735	2.158	0.054	2.
Repair/sale motors	**RSM**	6.870	6.486	4.630	2.427	0.100	2.
Transport services; Support for Transport	**TRA**	6.909	6.569	4.716	2.629	0.097	2.
Post/Telecoms	**POT**	5.205	4.556	3.529	1.934	0.133	1.
Financial intermediation; Real estate; Real estate	**FIN**	6.074	5.401	4.862	2.041	0.118	2.
Computer services/R&D; Other Business services	**BUS**	5.561	4.869	3.030	1.841	0.103	2.

Table 5-8 (cont.)

Industry Group	*ln* labour productivity[a]	Exporting[c] Always (EXP_ always)	Never (EXP_ never)	Entered (EXP_ entry)	Exited (EXP_ exit)	entered/ exited (EXP_ both)	N
Agriculture/Forestry/Fish	3.993	0.121	0.792	0.013	0.029	0.046	3,555
Food/Beverages/Tobacco	3.111	0.126	0.637	0.020	0.180	0.037	5,341
Textiles/Cloth/Leather	3.918	0.445	0.464	0.025	0.048	0.019	3,848
Wood products, Paper/Printing	4.124	0.150	0.763	0.033	0.032	0.022	12,543
Coke/Chemicals, Rubber/Plastics	4.324	0.504	0.305	0.081	0.044	0.067	7,979
Non-metal minerals, Basic metals/fabricated, Fabricated metals	4.008	0.339	0.531	0.050	0.046	0.034	12,472
Machinery/Equipment; Office equip/Radio, TV; Electrical machinery; Medical/Precision; Motor vehicles/parts; Other transport	4.254	0.544	0.292	0.072	0.051	0.040	16,239
Manufacturing n.e.c.	3.927	0.299	0.575	0.056	0.044	0.025	6,786
Construction	4.229	0.031	0.933	0.014	0.015	0.007	21,468
Repair/sale motors	4.442	0.061	0.907	0.009	0.014	0.010	11,543
Transport services; Support for Transport	4.280	0.084	0.867	0.019	0.022	0.008	12,240
Post/Telecoms	3.272	0.071	0.878	0.017	0.018	0.015	2,201
Financial intermediation; Real estate; Real estate	4.033	0.049	0.917	0.012	0.013	0.009	32,382
Computer services/R&D; Other Business services	3.719	0.128	0.787	0.036	0.032	0.016	55,538

Notes: [a] £'000 2000 prices; [b] actual numbers; [c] Values are proportions. See Table 5-7 for variable definitions.
Source: calculations based on weighted *FAME*

Intermediate inputs (i.e. the cost of sales in the *FAME* database) are similarly deflated using PPI (inputs) index numbers (MM22), although for most non-manufacturing sectors only a PPI (output) index is available and thus is used here. Tangible assets are valued at book values in the *FAME* database; thus these are rebased using price indices for fixed investment (MM17) at a disaggregated industry level. The age of the firm is obtained from information provided on the year of incorporation of the firm; only unconsolidated accounts from *FAME* are used, and this variable refers to the age of the company acquiring another when this occurred. Labour productivity is measured as gross output per employee.

The variable in *FAME* that records overseas turnover is used with regard to the information on exporting. This is deflated using PPI (output) figures in the same way that gross output is converted to a constant price basis. Given data are available on entry and exit for 1996-2004, it is possible to divide firms into various categories based on their exporting status, which will help shed light on how the churning in export markets condition the exporting-productivity relationship − those that always exported, those that never exported, those that entered into exporting during the period observed, those that exited, and lastly a small proportion of firms that started and then stopped exporting more than once. As can be seen, the sub-groups EXP_always and EXP_never dominate every industry group, with the greatest proportion of firms that always exported concentrated in the manufacturing sector of the economy.

5.2.2 Descriptive Analysis of Productivity Differences

Before undertaking any econometric analysis of the nexus between exporting and productivity, this section considers whether exporters (and foreign-owned firms) have higher levels of labour productivity or TFP. Following the discussion in the previous section (pp. 182-188) and based on the baseline model of production function in Euqation (5.1), to obtain the estimate of TFP, an augmented production function can be estimated as follows −

$$\mathrm{y_{it}} = \alpha_0 + \alpha_{\mathrm{E}}\mathrm{e_{it}} + \alpha_{\mathrm{M}}\mathrm{m_{it}} + \alpha_{\mathrm{K}}\mathrm{k_{it}} + \alpha_{\mathrm{T}}\mathrm{t} + \gamma \mathrm{X_{it}} + \varepsilon_{\mathrm{it}}$$

(5.10)

where y, e, m and k refer to the logarithms of real gross output, employment, intermediate inputs and tangible assets in firm *i* in time *t*. To incorporate a vector of variables, X, that determine TFP, TFP growth in this instance is defined as (dropping sub-scripts) –

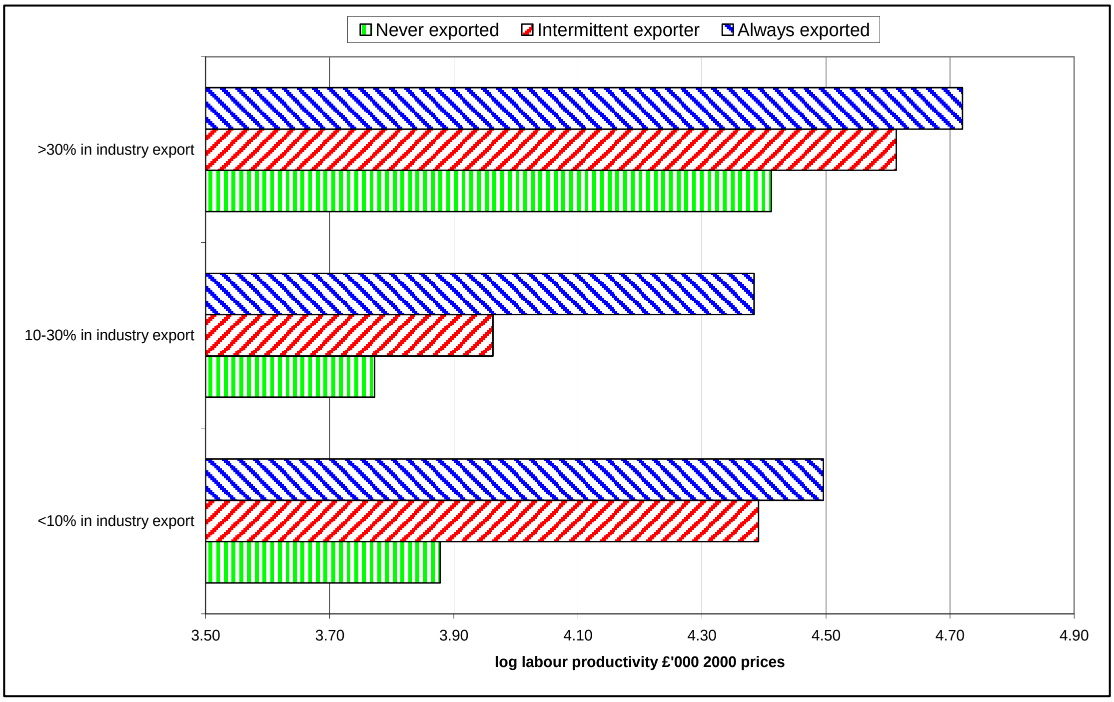
$$ln\dot{TFP} = \hat{\alpha}_T + \hat{\gamma}\dot{X} \equiv \dot{y} - \hat{\alpha}_E\dot{e} - \hat{\alpha}_M\dot{m} - \hat{\alpha}_K\dot{k}$$

(5.11)

Since the problem under consideration is to understand the causes of TFP (in particular the role of exporting), the preferred approach to estimating TFP is to directly include the determinants of output (and thus TFP) into the production function, as this avoids any problems of statistical inefficiency and omitted variable bias associated with estimating a two-stage model using a growth accounting approach. Moreover, this method also allows the direct test of whether such determinants are statistically significant.

The values of the output elasticities α_i are obtained when estimating an extended production function for each of 14 industry sub-groups as discussed below (see Equation (5.18) as set out in the empirical model), and this approach also allows the α_i to vary across different sub-groups depending on their export status. Note, in this descriptive analysis, FDI firms are assumed to have the same output elasticities as UK-owned firms, which is an approximation. Moreover, the individual firm TFP figures used here are normalised against the average TFP figure across all firms in 1996, to provide relative indicators of TFP.

Figure 5-3: Average labour productivity by exporting sub-groups and export intensity of industry, UK, 1996-2004



Source: the weighted *FAME*

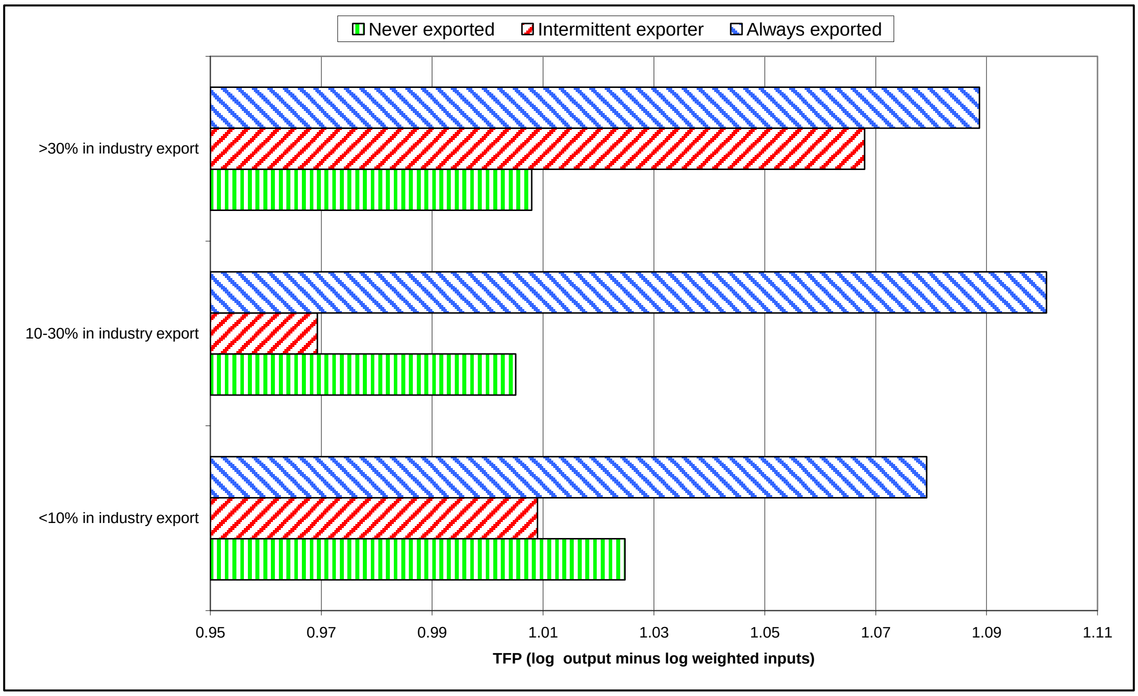
Figure 5-3 divides the weighted *FAME* dataset into firms that never export, those that export during some of the period in which they are observed and those that export in every year they are observed. Industries are also allocated into 3 sub-groups depending on the proportion of firms there that export (see Table 5-14 for details on dividing industries into sub-groups). The diagram shows that based on average labour productivity (in constant prices), firms that always export have the highest productivity levels, followed by intermittent exporters, and lastly (often at a significantly lower level) firms serving domestic market only. There is evidence that overall labour productivity is highest in those industries where exporting is more prevalent, but this is somewhat misleading as such industries (mostly dominated by heavy manufacturing) tend to be more capital intensive, leading to higher output-per-employee[86].

The same breakdown of firms in term of TFP by sub-groups is provided in Figure 5-4. This confirms that firms that always export have the highest productivity levels, vis-à-vis non exporters; and that this pattern exists across each industry sub-group. Figure 5-4 also shows that intermittent exporters (viz. those new to exporting, those who cease selling overseas and those who both stop and start

[86] This reinforces the arguments put forward previously (p.183) about labour productivity being a less useful indicator of productivity – it is dependent on not just technical progress and efficiency gains, but also the intensity of use of other factors of production.

exporting) only tend to have relatively high levels of TFP in those industries where exporting is common across firms. In other industry sub-groups, there is some evidence that intermittent exporters have lower TFP.

Figure 5-4: Average total factor productivity by exporting sub-groups and export intensity of industry, UK, 1996-2004



Source: the weighted *FAME*

Separately identifying foreign-owned firms (both exporting and non-exporting) produces a slightly different picture with regard to productivity (Figure 5-5 and Figure 5-6). Figure 5-5 uses data on labour productivity and shows that exporters that are also foreign-owned have the highest productivity in each industry sub-group, followed in terms of ranking by foreign-owned non-exporters. That is, and deriving from Dunning (1988)'s 'eclectic paradigm', foreign-owned firms exhibit some competitive advantages (or monopolistic advantages)[87] over their domestic rivals, whether they also export outside the host country or not. If there are specific advantages attached to locating in the host country, it could be expected that the motive for FDI to be at least in part explained by 'technology exploitation' or alternatively, 'market seeking', based on the specific advantages of MNEs. This suggests that foreign-owned firms operating in the UK are less useful as a comparator sub-group when considering whether exporters

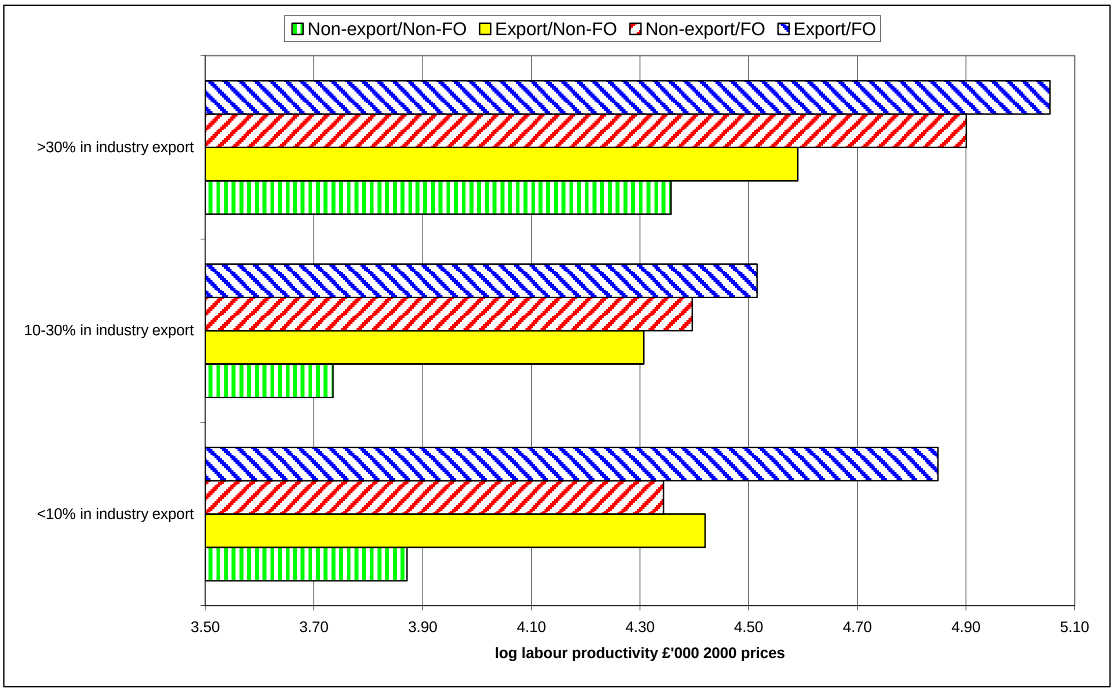
[87] Based on the monopolistic/ownership advantage theory by Hymer (1976), these firm-specific advantages include cost advantages (the ability to acquire factors of production at a lower cost), the control of a superior production function, better product differentiation, better distribution channels, or technological and marketing expertise (*c.f.* Caves, 1971).

have relatively higher productivity, since non-exporting foreign-owned firms have productivity advantages that do not necessarily stem from exporting to overseas markets (indeed FDI itself is an alternative strategy of internationalisation to exporting – see Head and Ries, 2003; Helpman *et al.*, 2004; and Girma *et al.*, 2005). This provides one of the reasons for the exclusion of such FDI firms when estimating the export-productivity relationship in subsequent sections [88].

Figure 5-5 confirms that UK-owned non-exporters have the lowest levels of labour productivity, although labour productivity in this sub-group is relatively high for those firms located in export intensive industries. In terms of TFP, Figure 5-6 suggests there is a stricter rank ordering from exporting foreign-owned firms to non-exporting MNE subsidiaries, to UK-owned exporters and lastly UK-owned non-exporters (although in those industries where some 10-30% of firms export there is evidence that foreign-owned non-exporting subsidiaries have the lowest levels of TFP).

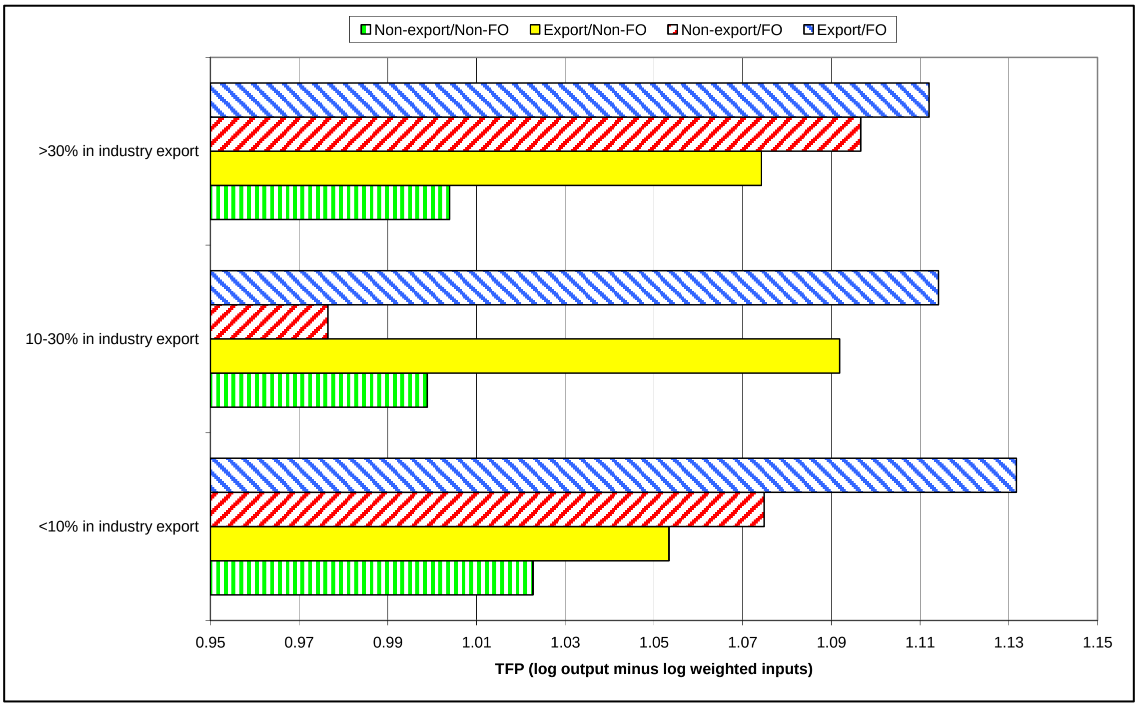
[88] Admittedly, this productivity advantage in foreign-owned firms may not merely stem from foreign ownership but also multinationality *per se*. Thus UK multinationals may also be expected to have potentially higher productivity which is not only associated with exporting but outward direct investments (ODI), and thus would ideally be excluded from subsequent analysis of exporting. Unfortunately, there is no information in the *FAME* to separately identify UK MNEs to investigate this possibility further.

Figure 5-5: Average labour productivity by exporting and foreign-owned sub-groups and export intensity of industry, UK, 1996-2004



Source: the weighted *FAME*

Figure 5-6: Average total factor productivity by exporting and foreign-owned sub-groups and export intensity of industry, UK, 1996-2004



Source: the weighted *FAME*

In summary, the information provided in Figure 5-3 to Figure 5-6 implies that firms that export do have (significant) productivity advantages when compared with (non foreign-owned) non-exporters. To confirm this, the next part of analysis begins by comparing the average TFP levels for various sub-groups at the 2-digit level of industrial classification.

As shown in Table 5-9, firstly, those that export in year *t* have significantly higher productivity when compared to non-exporters in *t*, for almost all the industries considered (*c.f.* the first set of results in Table 5-9). Only exporting firms operating in the *agriculture*, *fishing & forestry*; *basic & fabricated metal products*; *electrical machinery*; and *computer/R&D sectors* do not on average have higher TFP compared to non-exporters. Similarly, foreign-owned subsidiaries (whether they are engaged in exporting or not) generally have higher productivity than UK-owned non-exporters; but such subsidiaries do not significantly out-perform UK-owned exporters in 12 out of the 30 industry groups while in 4 industry groups (viz. *post & telecoms*; *renting; computer services & R&D*; and *other business services*) UK-owned exporters have higher average levels of TFP. Firms that are always observed as exporting in the *FAME* database generally do better compared to those that never export (in 4 industries this is not the case, and in the renting sector permanent exporters do worse).

Table 5-9: Average TFP by various sub-groups and industries, UK, 1996-2004

Industry (SIC2003 group)	All exporters vs. all non-exporters			All Foreign-owned vs. UK-owned non-exporter			All Foreign-owned vs. UK-owned exporter		
Agriculture/Forestry/Fish (A/B)	0.98	1.00	*0.8*	1.05	0.99	*-2.4*	1.05	0.96	*-2.6*
Food/Beverages/Tobacco (DA)	1.05	0.68	*-10.8*	0.85	0.68	*-9.0*	0.85	1.05	*5.0*
Textiles/Cloth/Leather (DB/DC)	1.05	0.96	*-5.8*	1.36	0.96	*-10.3*	1.36	1.02	*-3.6*
Wood products (DD)	1.13	0.88	*-11.3*	1.37	0.88	*-10.5*	1.37	1.12	*-3.1*
Paper/Printing (DE)	1.16	1.03	*-11.6*	1.16	1.03	*-4.2*	1.16	1.16	*0.1*
Coke/Chemicals (DF/DG)	1.18	1.05	*-4.5*	1.20	1.06	*-3.1*	1.20	1.17	*-1.2*
Rubber/Plastics (DH)	1.06	0.99	*-4.0*	1.01	1.00	*-0.6*	1.01	1.07	*2.6*
Non-metal minerals (DI)	1.04	0.96	*-4.7*	1.09	0.96	*-6.2*	1.09	1.03	*-2.4*
Basic metals/fabricated (DJ)	1.02	1.00	*-1.0*	1.11	0.99	*-5.3*	1.11	1.01	*-3.7*
Fabricated metals (DJ pt)	1.02	0.99	*-2.9*	1.07	0.99	*-3.9*	1.07	1.01	*-4.6*
Machinery/Equipment (DK)	1.07	0.99	*-6.2*	1.08	0.98	*-6.0*	1.08	1.06	*-1.9*
Office equip/Radio, TV (DI pt)	1.12	0.96	*-2.9*	1.13	0.92	*-3.1*	1.13	1.12	*-0.2*
Electrical machinery (DI pt)	1.07	1.04	*-1.3*	1.14	0.99	*-3.9*	1.14	1.07	*-2.6*
Medical/Precision (DI pt)	1.14	1.02	*-4.3*	1.12	1.00	*-2.7*	1.12	1.14	*0.5*
Motor vehicles/parts (DM pt)	1.04	1.01	*-1.1*	1.01	1.02	*0.5*	1.01	1.03	*0.6*
Other transport (DM pt)	1.12	1.00	*-3.5*	1.06	1.01	*-1.0*	1.06	1.12	*1.2*
Manufacturing n.e.c. (DN)	1.09	0.92	*-10.2*	1.09	0.92	*-7.0*	1.09	1.09	*-0.1*
Construction (F)	1.06	0.97	*-7.7*	1.07	0.97	*-4.8*	1.07	1.04	*-1.2*
Repair/sale motors (G pt)	1.06	1.00	*-11.0*	1.09	1.00	*-11.3*	1.09	1.05	*-4.8*
Wholesale trade (G pt)	1.10	1.04	*-11.5*	1.11	1.02	*-11.5*	1.11	1.09	*-1.5*
Retail trade (G pt)	1.10	1.01	*-22.4*	1.16	1.00	*-32.1*	1.16	1.08	*-12.1*
Hotels/restaurants (H)	0.87	1.08	*3.9*	1.07	1.08	*0.2*	1.07	0.86	*-3.6*
Transport services (I pt)	1.05	0.94	*-7.4*	1.05	0.94	*-3.2*	1.05	1.04	*-0.1*
Support for Transport (I pt)	1.08	0.99	*-7.1*	1.07	0.98	*-5.9*	1.07	1.08	*0.6*
Post/Telecoms (I pt)	1.07	0.94	*-7.9*	0.96	0.94	*-0.9*	0.96	1.07	*3.9*
Financial intermediation (J)	1.11	1.06	*-5.1*	1.10	1.06	*-2.8*	1.10	1.10	*0.1*
Real estate (K pt)	1.00	1.10	*2.9*	1.07	1.10	*0.8*	1.07	1.00	*-1.7*
Renting (K pt)	1.14	1.06	*-2.9*	1.00	1.06	*2.7*	1.00	1.17	*4.8*
Computer services/R&D (K pt)	1.11	1.09	*-1.0*	1.02	1.11	*3.5*	1.02	1.10	*2.6*
Other Business services (K pt)	1.09	0.96	*-12.4*	0.98	0.97	*-0.8*	0.98	1.09	*6.2*
Total	1.08	1.02	*-40.0*	1.08	1.02	*-24.9*	1.08	1.07	*-1.7*

Notes: figures in italics are *t*-tests of differences in the average TFP values across each sub-group.
Source: the weighted *FAME.*

Table 5-9 (cont.)

Industry (SIC2003 group)	All permanent exporter vs. all never exported			Foreign-owned exporter vs. foreign-owned non-exporter		
Agriculture/Forestry/Fish (A/B)	1.02	1.00	*-0.9*	1.02	1.15	*2.7*
Food/Beverages/Tobacco (DA)	1.12	0.83	*-9.8*	1.06	0.52	*-8.5*
Textiles/Cloth/Leather (DB/DC)	1.05	0.96	*-5.7*	1.41	1.07	*-2.5*
Wood products (DD)	1.14	0.87	*-11.1*	1.25	1.43	*0.6*
Paper/Printing (DE)	1.17	1.03	*-11.1*	1.22	1.01	*-3.7*
Coke/Chemicals (DF/DG)	1.18	1.03	*-3.7*	1.24	0.97	*-3.9*
Rubber/Plastics (DH)	1.06	1.00	*-3.4*	1.02	0.98	*-0.5*
Non-metal minerals (DI)	1.07	0.96	*-0.6*	1.09	1.10	*0.2*
Basic metals/fabricated (DJ)	1.02	1.01	*-5.5*	1.10	1.13	*0.5*
Fabricated metals (DJ pt)	1.02	0.97	*-5.7*	1.09	1.03	*-2.4*
Machinery/Equipment (DK)	1.07	0.99	*-7.5*	1.09	1.05	*-1.1*
Office equip/Radio, TV (DI pt)	1.12	0.97	*-3.1*	1.13	1.14	*0.1*
Electrical machinery (DI pt)	1.08	1.03	*-1.8*	1.09	1.20	*1.6*
Medical/Precision (DI pt)	1.14	1.03	*-3.6*	1.14	1.08	*-1.5*
Motor vehicles/parts (DM pt)	1.03	1.00	*-1.2*	1.06	0.94	*-1.7*
Other transport (DM pt)	1.13	0.99	*-4.1*	1.14	0.92	*-3.0*
Manufacturing n.e.c. (DN)	1.09	0.92	*-9.8*	1.10	1.07	*-0.6*
Construction (F)	1.05	0.97	*-6.1*	1.13	1.03	*-2.4*
Repair/sale motors (G pt)	1.06	1.00	*-9.5*	1.12	1.08	*-2.5*
Wholesale trade (G pt)	1.11	1.03	*-15.1*	1.11	1.10	*-0.3*
Retail trade (G pt)	1.11	1.01	*-20.9*	1.20	1.15	*-4.1*
Hotels/restaurants (H)	0.67	1.08	*4.6*	1.09	1.07	*-0.2*
Transport services (I pt)	1.04	0.94	*-6.4*	1.07	1.03	*-0.6*
Support for Transport (I pt)	1.09	0.98	*-6.5*	1.06	1.08	*0.8*
Post/Telecoms (I pt)	1.06	0.94	*-7.0*	1.07	0.93	*-3.4*
Financial intermediation (J)	1.11	1.06	*-3.3*	1.13	1.08	*-1.7*
Real estate (K pt)	0.98	1.10	*2.9*	1.02	1.07	*0.8*
Renting (K pt)	1.17	1.07	*-3.8*	0.89	1.04	*3.2*
Computer services/R&D (K pt)	1.09	1.11	*0.7*	1.15	0.86	*-5.8*
Other Business services (K pt)	1.10	0.96	*-11.6*	1.08	0.88	*-6.2*
Total	1.09	1.02	*-33.8*	1.12	1.05	*-9.9*

When FDI firms that export are compared to non-exporting FDI firms, Table 5-9 shows that half of the 30 industry groups have insignificant differences between the two sub-groups, while in 12 industries exporters do better than non-exporters (in *agriculture, fishing & forestry*; *electrical machinery*; and *renting* MNE subsidiaries that do not export perform better).

In summary, Table 5-9 confirms that generally exporters and foreign-owned firms have on average higher levels of TFP, but foreign-owned firms are not always better than UK-owned exporters and exporting by foreign-owned firms only seems to confer a TFP advantage in half of the industries considered. This again suggests that MNE subsidiaries gain advantages that are not directly attributable to exporting *per se*, and that it may be more useful to exclude this group of firms when examining the impacts of exporting on productivity.

Admittedly, one can argue that comparing mean values for productivity levels across industries is not as strong a test as considering whether the distribution of productivity for one sub-group dominates that of a different sub-group. Thus, a similar exercise to that used by Girma *et al.* (2005) and Wagner (2006) is undertaken to test the rank ordering of the productivity distribution of firms that differ in their involvement in international markets. Calculating a two-sided Kolmogorov-Smirnov statistic, it is possible to test whether the productivity distribution of one sub-group of firms (e.g. exporters) lies to the right of another sub-group (e.g. non-exporters). If so, there is shown to be first-order stochastic dominance between such (random) variables, and this proves to be a stricter test than simply comparing average productivity levels across sub-groups.

Table 5-10 presents the results obtained when applying the Kolmogorov-Smirnov test to the data on TFP levels. Note, for each group tested, the null hypothesis being tested is that the difference between the two distributions is favourable to one sub-group over the other, and thus being able to reject this null for one sub-group (e.g. non-exporters) would suggest that the other sub-group (e.g. exporters) have a distribution to the right of the rejected sub-group. Note, the values reported in Table 5-10 measure the greatest difference between the two sub-groups, and a positive value means that a sub-group lies to the left of the opposing sub-group.

Firstly, it can be confirmed that in every industry examined, firms that export have a distribution that lies significantly to the right of non-exporters, and the largest difference between the two distributions is always greater than 0.14, and often above 0.2. These results show even more pronounced differences than those presented in Table 5-9 where differences in the mean levels of TFP in various groups are compared.

Table 5-10: Two-sample Kolmogorov-Smirnov tests on the distribution of TFP by various sub-groups and industries, UK 1996-2004

		Difference favourable to:		Difference favourable to:	
Industry (SIC2003 group)	Sub-group	All exporters vs.	All non-exporters	All permanent Exporters vs.	All never exported
Agriculture/Forestry/Fish (A/B)	**AGF**	-0.049	0.155**	-0.049	0.154**
Food/Beverages/Tobacco (DA)	**FBT**	-0.001	0.241**	-0.001	0.259**
Textiles/Cloth/Leather (DB/DC)	**TCL**	-0.001	0.252**	-0.001	0.267**
Wood products (DD)	**WPP**	-0.004	0.312**	-0.001	0.351**
Paper/Printing (DE)		-0.004	0.255**	-0.006	0.273**
Coke/Chemicals (DF/DG)	**CRR**	-0.013	0.199**	-0.028	0.219**
Rubber/Plastics (DH)		-0.005	0.142**	-0.004	0.144**
Non-metal minerals (DI)	**MET**	-0.028	0.157**	-0.023	0.169**
Basic metals/fabricated (DJ)		-0.002	0.230**	-0.002	0.237**
Fabricated metals (DJ pt)		-0.008	0.215**	-0.005	0.240**
Machinery/Equipment (DK)	**ENG**	-0.002	0.199**	-0.000	0.208**
Office equip/Radio, TV (DI pt)		-0.026	0.177**	-0.037	0.161**
Electrical machinery (DI pt)		-0.039	0.264**	-0.041	0.316**
Medical/Precision (DI pt)		-0.008	0.261**	-0.010	0.281**
Motor vehicles/parts (DM pt)		-0.035	0.179**	-0.003	0.273**
Other transport (DM pt)		-0.033	0.245**	-0.038	0.301**
Manufacturing n.e.c. (DN)	**OMF**	-0.001	0.217**	-0.001	0.241**
Construction (F)	**CON**	-0.008	0.262**	-0.010	0.289**
Repair/sale motors (G pt)	**RSM**	-0.002	0.213**	-0.002	0.228**
Transport services (I pt)	**TRA**	-0.011	0.276**	-0.015	0.285**
Support for Transport (I pt)		-0.009	0.178**	-0.009	0.218**
Post/Telecoms (I pt)	**POT**	-0.011	0.151**	-0.011	0.144**
Financial intermediation (J)	**FIN**	-0.049**	0.220**	-0.060**	0.239**
Real estate (K pt)		-0.083**	0.149**	-0.091**	0.143**
Renting (K pt)		-0.017	0.317**	-0.016	0.358**
Computer services/R&D (K pt)	**BUS**	-0.001	0.142**	-0.001	0.160**
Other Business services (K pt)		-0.023**	0.220**	-0.027**	0.238**

Notes: ** denotes null rejected at 1% level; * null rejected at 5% level.
Source: calculations based on weighted *FAME*.

Figure 5-7: Productivity level differences between exporters and non-exporters in financial intermediation, UK, 1996-2004

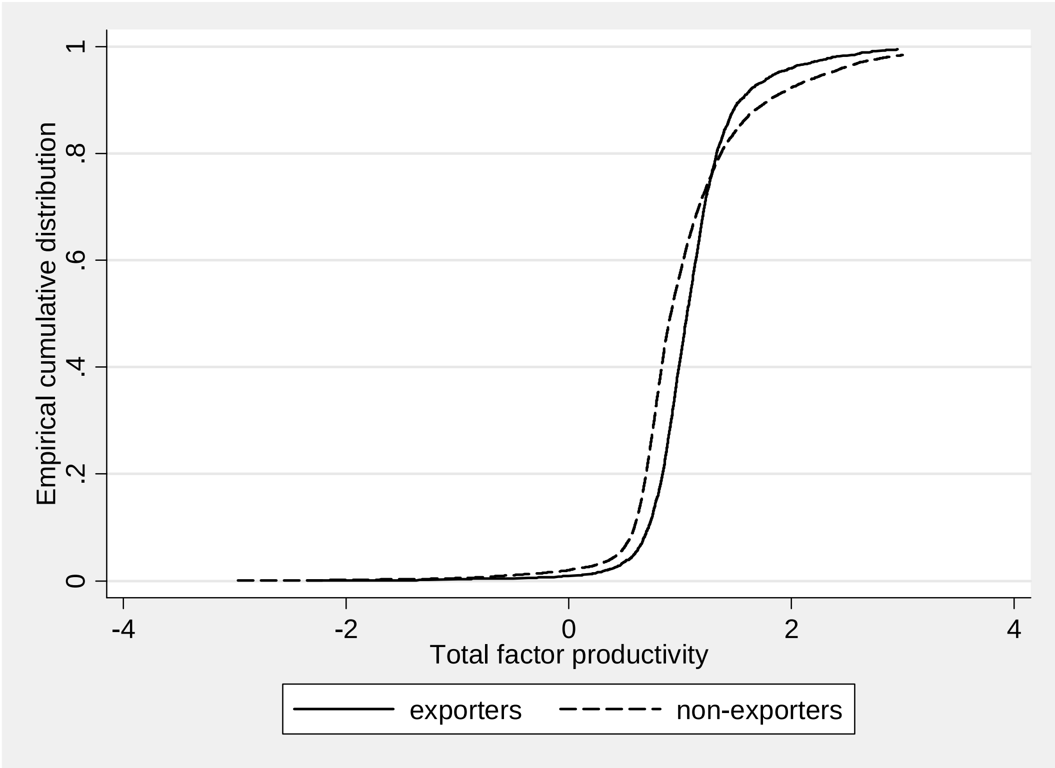
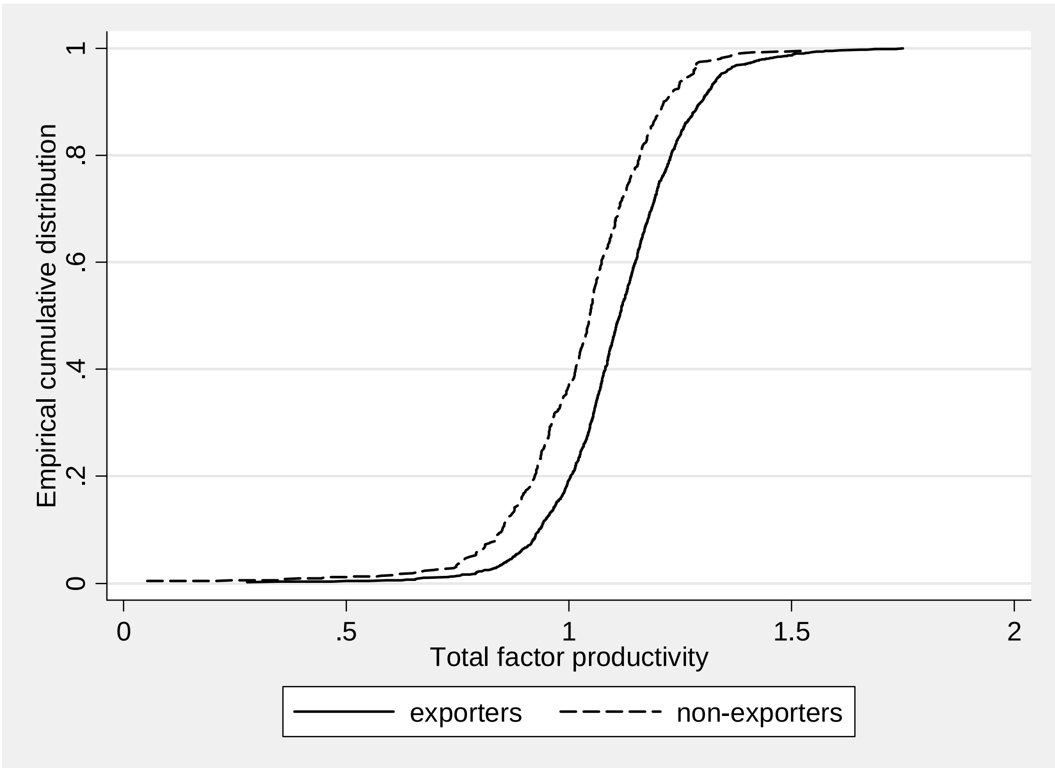


Figure 5-8: Productivity level differences between exporters and non-exporters in Basic metals/fabricated sector, UK, 1996-2004



However, for three industries (viz. *financial intermediation, real estate* and *other business services*) it is also possible to reject the null that the distribution for exporters is more favourable compared to non-exporters. In these industries, exporters dominate non-exporters for a large part of the distribution of TFP values, but at some level (usually at high levels of TFP) there is a cross-over and non-exporters dominate exporters. This could be illustrated in Figure 5-7 and Figure 5-8: the former presents the empirical cumulative distributions for the financial intermediation sector, where both null hypotheses relating to dominance are rejected; while the latter presents a similar picture for the basic and fabricated metals sector where exporters always dominate non-exporters. Table 5-10 also confirms that the distribution of TFP for permanent exporters dominates that for those that did not export at any time during 1996-2004.

The results obtained here therefore confirm those presented by Girma *et al.* (*op. cit.*) that the productivity distribution of exporters dominate that of non-exporters in the UK (although this analysis also provides additional evidence here to cover non-manufacturing). Nevertheless, in addition to distinct data sources, there are major differences between the approach taken by Girma *et al.* and the one used here: using the *OneSource* data, they have a sample of some 11,824 observations (covering 3,799 firms) in manufacturing for 1990-1996, which are not weighted to make it representative of the UK population, whereas the data used in this thesis contain 326,906 observations for 81,819 firms covering most of the industries that produce marketed output during 1996 to 2004, weighted using *ARD* data. Girma *et al.* (*op. cit.*) also employ a model of growth accounting index number that imposes constant returns-to-scale and perfect competition, which are very strict assumptions indeed.

5.3 Empirical Modelling of the Export-Productivity Relationship

Having shown that exporting firms generally have higher levels of TFP, the new focus here turns to multivariate statistical analysis of the links between exporting and productivity (pre- and post-entry). That is, the self-selection and 'learning-by-exporting' hypotheses reviewed in Chapter 4 are tested here. As hinted earlier in this chapter when describing productivity differences, only data on UK-owned firms is used in the econometric modelling of productivity.

5.3.1 Testing the Self-Selection Hypothesis

In testing the self-selectivity of exporters, the following model is first estimated to identify the probability of exporting using the following panel probit model –

$$P(Export_{it} = 1) = \phi(lnLP_{it-1}, lnAge_{it-1}, Intang_{it-1}, Size_{it-1}, Industry_{it,} Region_{it}) \quad \textbf{(5.12)}$$

where $Export$ is coded 1 if the firm exported at any time during 1996-2004; LP is labour productivity[89]; Age is the age of the firm; $Intang$ is coded 1 if the firm has non-zero intangible assets[90]; $Size$ represents a set of dummy variables that indicate whether the firm belongs to one of the following 4 size bands: 10-19, 20-49, 50-199 or 200+ employees; and $Industry$ and $Region$ are dummy variables indicating each industry sub-group or Government Office region.

The results obtained from estimating Equation (5.12) are presented in Table 5-11. Lagged values of the right-hand-side variables have been utilised (except for non-changing region and industry dummy variables) to reduce any bias due to simultaneity between these variables and the probability of exporting. Table 5-11 reports the marginal effects of increasing size, labour productivity, age and having non-zero intangible assets, on overcoming barriers to entering export markets. Larger firms, who presumably have access to more resources, are much more likely to engage in exporting; moreover, firms with higher labour productivity in period *t-1* are significantly more likely to sell overseas in period *t*, although the strength of this relationship varies across industry groups (e.g. doubling labour productivity increases the probability of exporting, *cet. par.*, by over 21% in the *textiles*, *clothing* and *leather sector*, whereas the comparable

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[89] Labour productivity (rather than TFP) is used here in estimating the probability of exporting, since the results from the probit model (i.e. the selectivity terms) are needed subsequently when estimating the 'control function' production function model (see next section).

[90] Here these non-monetary assets usually refer to corporate intellectual property (e.g. patents, copyrights, trademarks, etc.), innovative activities, advertising, goodwill, brand recognition and similar intangible assets. There is sufficient ambiguity of exactly what should be included as intangible assets (and issues over how to measure such assets – see, for example, Webster and Jensen, 2006) and thus a dummy variable has been chosen rather than the actual monetary amount reported in *FAME*.

figure is only 0.7% in the *repair/sale of motor vehicles* sector. Generally, the impact of productivity on the probability of exporting is more pronounced in the manufacturing sector.

Table 5-11: Determinants of exporting by industries, UK 1996-2004 (*c.f.* Equation (5.12))

Independent variables \ Industries	AGF			FBT			TCL		
	$\partial\hat{p}/\partial x$	*z*-value	Means	$\partial\hat{p}/\partial x$	*z*-value	Means	$\partial\hat{p}/\partial x$	*z*-value	Means
10-19 employees $_{(t-1)}$	-0.058	-2.58	0.178	-0.113	-3.45	0.207	0.192	6.01	0.152
20-49 employees $_{(t-1)}$	0.296	8.42	0.131	-0.100	-3.26	0.308	0.442	19.66	0.283
50-199 employees $_{(t-1)}$	0.316	9.35	0.172	0.138	3.92	0.223	0.503	25.22	0.273
200+ employees $_{(t-1)}$	0.557	12.93	0.073	0.280	6.57	0.121	0.419	28.08	0.108
ln labour productivity $_{(t-1)}$	0.030	3.89	4.030	0.137	11.76	4.043	0.214	14.82	3.969
having intangible assets or not $_{(t-1)}$	-0.043	-1.95	0.126	0.142	5.02	0.220	0.109	2.94	0.103
ln age $_{(t-1)}$	0.076	7.74	2.921	0.008	0.68	2.801	0.062	5.16	2.912
North East	-0.160	-14.66	0.031	-0.153	-2.63	0.044	0.232	2.68	0.007
Yorkshire-Humberside	-0.101	-4.94	0.047	-0.041	-0.85	0.097	0.329	11.18	0.100
North West	-0.162	-14.68	0.048	0.115	1.98	0.060	0.114	2.26	0.146
West Midlands	-0.159	-14.36	0.046	0.570	15.16	0.090	0.222	5.25	0.112
East Midlands	-0.068	-3.63	0.132	0.149	2.61	0.066	0.330	10.65	0.144
South West	-0.166	-13.98	0.093	0.185	3.30	0.074	0.316	9.66	0.026
Eastern England	-0.159	-11.77	0.176	0.157	3.02	0.092	-0.011	-0.13	0.035
London	-0.101	-5.47	0.065	0.083	1.86	0.237	0.302	8.10	0.222
Scotland	-0.124	-8.55	0.087	0.118	2.40	0.113	0.159	3.23	0.132
Wales	-0.145	-12.25	0.022	-0.100	-1.68	0.038	0.297	8.27	0.021
Northern Ireland	–	–	–	0.487	1.82	0.001	-0.259	-1.42	0.003
No. of Obs.	2303			2522			2487		

Notes: $\partial\hat{p}/\partial x$ are marginal effects for each independent variable on the propensity to export (for binary variables, these are the effects of a discrete change from 0 to 1) and their corresponding *Z* statistics. Refer to Table 5-8 for details of industry codes. Missing results for any region (e.g. Northern Ireland) is due to too few observations (leading to estimation problems); the South East region comprises the benchmark. SIC industry dummies were included but not reported in the table.

Table 5-11 (cont.)

Independent variables \ Industries	WPP $\partial\hat{p}/\partial x$	WPP *z*-value	WPP Means	CRR $\partial\hat{p}/\partial x$	CRR *z*-value	CRR Means	MET $\partial\hat{p}/\partial x$	MET *z*-value	MET Means
10-19 employees $_{(t-1)}$	-0.008	-0.52	0.211	-0.061	-2.76	0.121	0.110	6.40	0.232
20-49 employees $_{(t-1)}$	0.161	9.43	0.194	0.133	10.86	0.211	0.321	21.26	0.187
50-199 employees $_{(t-1)}$	0.276	16.36	0.230	0.251	19.69	0.347	0.481	38.81	0.261
200+ employees $_{(t-1)}$	0.511	21.52	0.061	0.250	26.72	0.179	0.480	47.57	0.053
ln labour productivity $_{(t-1)}$	0.114	16.80	4.212	0.025	3.49	4.363	0.160	17.57	4.040
having intangible assets or not $_{(t-1)}$	0.087	5.45	0.144	0.100	7.12	0.175	0.280	16.38	0.120
ln age $_{(t-1)}$	0.044	8.71	2.609	0.024	3.98	2.853	0.047	6.27	2.927
North East	-0.112	-5.24	0.036	0.127	4.57	0.015	-0.164	-4.80	0.034
Yorkshire-Humberside	0.055	2.08	0.044	0.126	9.31	0.097	0.019	0.71	0.081
North West	0.059	2.49	0.061	0.092	5.76	0.152	-0.103	-4.06	0.085
West Midlands	0.065	2.15	0.038	0.027	1.30	0.093	0.096	4.50	0.180
East Midlands	-0.032	-1.52	0.055	0.091	5.05	0.068	-0.204	-8.20	0.078
South West	-0.003	-0.15	0.078	0.017	0.73	0.080	-0.207	-8.20	0.076
Eastern England	0.014	0.74	0.107	0.099	5.80	0.147	-0.169	-7.48	0.123
London	0.024	1.70	0.298	0.010	0.53	0.150	-0.121	-5.16	0.104
Scotland	-0.076	-3.52	0.043	0.058	1.99	0.030	0.083	2.54	0.043
Wales	-0.026	-0.90	0.028	0.117	6.54	0.033	-0.246	-8.24	0.041
Northern Ireland	-0.170	-3.07	0.002	0.157	8.66	0.008	-0.347	-4.86	0.003
No. of Obs.	8375			5551			8633		

Table 5-11 (cont.)

Independent variables \ Industries	ENG			OMF			CON		
	$\partial\hat{p}/\partial x$	*z*-value	Means	$\partial\hat{p}/\partial x$	*z*-value	Means	$\partial\hat{p}/\partial x$	*z*-value	Means
10-19 employees $_{(t-1)}$	0.091	9.03	0.138	0.267	11.36	0.194	0.064	7.45	0.163
20-49 employees $_{(t-1)}$	0.139	15.61	0.235	0.264	10.75	0.162	0.112	10.50	0.134
50-199 employees $_{(t-1)}$	0.312	37.35	0.328	0.437	22.40	0.285	0.159	13.56	0.140
200+ employees $_{(t-1)}$	0.260	47.15	0.119	0.511	29.45	0.080	0.322	12.22	0.033
ln labour productivity $_{(t-1)}$	0.062	10.92	4.278	0.117	12.48	4.039	0.013	6.16	4.318
having intangible assets or not $_{(t-1)}$	0.086	8.66	0.179	0.145	5.97	0.146	0.084	6.69	0.051
ln age $_{(t-1)}$	0.053	11.04	2.745	0.150	15.05	2.671	-0.001	-0.62	2.508
North East	-0.213	-6.48	0.028	-0.092	-1.29	0.014	-0.012	-1.45	0.031
Yorkshire-Humberside	0.042	2.60	0.069	-0.054	-1.64	0.111	0.001	0.17	0.049
North West	0.007	0.47	0.083	0.030	0.88	0.094	-0.018	-3.24	0.068
West Midlands	0.099	8.61	0.136	0.048	1.41	0.107	-0.027	-5.88	0.095
East Midlands	0.053	3.60	0.076	0.213	6.42	0.088	-0.011	-1.77	0.071
South West	0.066	4.65	0.078	0.156	4.46	0.088	-0.031	-6.86	0.101
Eastern England	0.027	1.99	0.125	-0.051	-1.50	0.091	-0.046	-12.47	0.151
London	-0.030	-2.11	0.134	-0.192	-7.27	0.173	-0.035	-8.57	0.199
Scotland	-0.186	-7.51	0.052	-0.242	-6.06	0.030	-0.032	-6.87	0.050
Wales	0.082	2.59	0.015	-0.191	-4.84	0.050	-0.016	-1.86	0.030
Northern Ireland	-0.089	-0.73	0.002	–	–	–	0.085	1.69	0.002
No. of Obs.	11794			4395			13430		

Table 5-11 (cont.)

Independent variables \ Industries	RSM $\partial\hat{p}/\partial x$	RSM *z*-value	RSM Means	TRA $\partial\hat{p}/\partial x$	TRA *z*-value	TRA Means	POT $\partial\hat{p}/\partial x$	POT *z*-value	POT Means
10-19 employees $_{(t-1)}$	0.095	8.33	0.252	0.037	3.02	0.178	0.059	1.92	0.143
20-49 employees $_{(t-1)}$	0.158	10.76	0.200	0.141	9.85	0.182	0.074	2.49	0.182
50-199 employees $_{(t-1)}$	0.220	9.49	0.087	0.168	10.54	0.167	0.173	3.44	0.100
200+ employees $_{(t-1)}$	0.253	5.16	0.017	0.264	9.29	0.055	0.156	2.02	0.033
ln labour productivity $_{(t-1)}$	0.007	2.09	4.469	0.043	11.88	4.301	0.029	3.81	3.558
having intangible assets or not $_{(t-1)}$	0.010	0.97	0.097	-0.006	-0.50	0.098	0.025	0.99	0.145
ln age $_{(t-1)}$	-0.002	-0.51	2.597	0.025	5.82	2.647	0.024	1.93	2.078
North East	-0.060	-8.35	0.018	-0.086	-7.71	0.028	0.360	2.59	0.013
Yorkshire-Humberside	0.111	4.13	0.035	0.028	1.56	0.061	-0.034	-1.34	0.057
North West	-0.011	-0.96	0.106	-0.047	-3.95	0.076	0.027	0.48	0.021
West Midlands	0.214	9.15	0.100	-0.082	-7.98	0.058	-0.058	-2.58	0.022
East Midlands	0.079	4.50	0.102	-0.032	-2.03	0.046	-0.090	-6.53	0.098
South West	-0.030	-3.38	0.131	-0.016	-1.00	0.061	-0.072	-4.24	0.080
Eastern England	0.022	1.71	0.121	-0.006	-0.47	0.137	0.129	2.42	0.059
London	0.051	3.35	0.117	-0.013	-1.23	0.328	0.026	1.28	0.294
Scotland	-0.050	-5.46	0.024	-0.087	-9.41	0.048	-0.071	-4.36	0.012
Wales	0.154	5.18	0.041	-0.072	-4.49	0.020	–	–	–
Northern Ireland	-0.044	-1.65	0.002	–	–	–	–	–	–
No. of Obs.	7416			8162			1146		

Table 5-11 (cont.)

Independent variables \ Industries	FIN			BUS		
	$\partial\hat{p}/\partial x$	*z*-value	Means	$\partial\hat{p}/\partial x$	*z*-value	Means
10-19 employees $_{(t-1)}$	0.046	6.90	0.143	0.215	23.91	0.127
20-49 employees $_{(t-1)}$	0.108	11.80	0.109	0.319	34.04	0.115
50-199 employees $_{(t-1)}$	0.177	14.95	0.084	0.390	39.78	0.104
200+ employees $_{(t-1)}$	0.319	16.27	0.039	0.374	25.42	0.046
ln labour productivity $_{(t-1)}$	0.014	9.67	4.097	0.083	34.85	3.823
having intangible assets or not $_{(t-1)}$	0.004	0.83	0.121	0.069	8.17	0.109
ln age $_{(t-1)}$	0.004	2.02	2.498	0.032	10.33	2.066
North East	-0.048	-7.78	0.013	0.031	1.72	0.024
Yorkshire-Humberside	-0.034	-7.08	0.051	-0.028	-2.28	0.040
North West	-0.027	-5.38	0.071	-0.005	-0.47	0.063
West Midlands	-0.039	-8.42	0.079	0.011	0.95	0.058
East Midlands	-0.020	-2.67	0.040	-0.046	-3.91	0.046
South West	-0.033	-6.41	0.058	-0.049	-4.64	0.057
Eastern England	-0.025	-4.91	0.089	-0.038	-4.56	0.120
London	0.018	3.81	0.375	0.023	3.32	0.335
Scotland	-0.028	-4.30	0.037	-0.066	-5.90	0.039
Wales	-0.029	-2.92	0.014	-0.037	-2.16	0.018
Northern Ireland	0.006	0.17	0.002	-0.064	-1.43	0.002
No. of Obs.	21081			32432		

Moreover, firms that have non-zero intangible assets are also generally much more likely to export, and this again points to a need to invest in highly productive resources that lead to greater capacities in order to overcome barriers to exporting. The average effect across all the industry sub-groups represented in Table 5-11 is that having intangible assets increases the likelihood of exporting by some 7%; however, in some industries (e.g. *food, beverages and tobacco*; *metals*; and *other manufacturing*) the impact is much larger showing around 19% on average, while in others there is no significant effect (e.g. *repair/sale of motor vehicles*; *transport services*; *post/telecoms*; and *finance*) or even a negative impact (e.g. *agriculture)*.

It is also worth noting that the findings here suggest the age of the firm in *t-1* is usually a major determinant of exporting, lending support to the process-based incremental models of internationalisation, as reviewed in Chapter 1 (pp.19-22). Doubling the (logged) age of the firm increases the probability of exporting by some 15% in the *other manufacturing* sector, with generally smaller (and often insignificant) impacts in non-manufacturing sectors.

Thus, the findings here on the determinants of exporting echo those obtained earlier from the exercise in Chapter 3 using the *CIS-ARD* data, which are also in line with the majority of previous studies: there was indeed strong self-selection by UK firms during 1996-2004, in all of the 14 industry sub-groups examined. The next section turns to testing whether there is also a 'learning-by-exporting' effect associated with post-entry sales to overseas markets.

5.3.2 Testing the 'Learning-by-exporting' Hypothesis

Econometric Modelling Approach

As discussed in Chapter 4 (pp.161-162), sample selectivity has been a particular issue when estimating models to determine the impact of exporting on productivity using micro-level data. This selectivity issue arises when comparisons are made between a 'treatment' group (e.g. those firms that participate in export markets in this case) and the rest of the population, when it is known or suspected that the treatment group do not constitute a random sample drawn from the population of all firms. To illustrate, the standard evaluation problem presented in the literature will be briefly reviewed here (*c.f.* Heckman, 2000; Heckman and Navarro-Lozano, 2004; Moffitt, 2004). The key issue is measuring without bias the outcome Y_i of the treatment effect on firms in terms of whether they receive the treatment EXP_i (i.e. participation in exporting) or not. That is –

$$E[Y_i | EXP_i = 1] - E[Y_i | EXP_i = 0] \tag{5.13}$$

To measure the impact using Equation (5.13), only the following information is available –

$$E[Y_i^1 | EXP_i = 1] - E[Y_i^0 | EXP_i = 0] \tag{5.14}$$

That is, the difference between what participants (EXP_i = 1) receiving the treatment experience in terms of outcome (Y_i^1) and what non-participants (EXP_i = 0) not receiving the treatment experience (Y_i^0). However, what is not observed is the outcome for participants had they not participated (i.e. $E[Y_i^0 | EXP_i = 1]$). This counterfactual can be used to expand (5.14) to give the following –

$$E[Y_i^1 - Y_i^0 | EXP_i = 1] + \{E[Y_i^0 | EXP_i = 1] - E[Y_i^0 | EXP_i = 0]\} \tag{5.15}$$

Equation (5.15) shows that a comparison between treated and untreated firms (in terms of what is observable – *c.f.* Equation (5.14)) equals the effect of 'treatment on the treated' (the first term in Equation (5.15)) plus a bias term (the second major term). As pointed out by Angrist *et al.* (1999), this bias would be zero if treated firms were randomly assigned (or at least assigned to ensure independence between EXP_i and Y_i^0)[91]. So, for example, if firms enter export markets independent of (say) the firm's potential productivity gain from exporting, then the bias term would be zero. But this conjecture seems unrealistic because selection into overseas markets is likely to be made taking account of the potential productivity gains from exporting, and it might be expected that those most likely to benefit will have a higher probability of breaking down barriers to exporting (and indeed other barriers to higher productivity). Put another way, and referring to the second term in Equation (5.15), bias occurs because the characteristics of the exporters are such that they achieve better performance than non-exporters even when they do not export, and this 'better performance' is correlated with the decision to export. Thus, the essential problem at the core of evaluating the effect of exporting is an attempt to estimate missing data; that is, to obtain an estimate of the unobserved counterfactual that is not biased because of any simultaneous relationship between the decision to export and the gains from exporting.

There are several approaches that attempt to eliminate the bias that arises from self-selection (*c.f.* Blundell *et al.*, 2005). The first considered here is matching. Essentially, this involves matching every exporting firm with another firm that has (very) similar characteristics but does not export (firms not exporting that have non-similar characteristics to those exporting are, of course, not included

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[91] Note if EXP_i is also independent of Y_i^1 (as would be expected in a 'laboratory-type' experiment where firms were randomly assigned) then $E[Y_i^1 - Y_i^0 | EXP_i = 1] = E[Y_i^1 - Y_i^0]$ and the 'treatment on the treated effect equals the unconditional average treatment effect (that is, the impact on an exporter drawn randomly from the population of firms).

in any analysis of the impact on productivity of exporting). Essentially, under the matching assumption exporters and non-exporters have the same (observable) attributes that impact on productivity (and the probability of exporting) except that one sub-group exports and the other does not; in other words, the outcome that would result in the absence of exporting is the same in both cases. Thus the non-exporting, matched sub-group constitutes the correct counterfactual for the missing information on the outcomes that exporters would have experienced, on average, if they had not exported[92].

Different approaches can be used to match firms, from using simple propensity score matching algorithms (Rosenbaum and Rubin, 1983), where such scores are obtained from a probit/logit regression approach, to covariate matching estimators (that use complicated algorithms to match firms who export with non-exporters). There are a number of issues with this matching procedure, including the need for a rich dataset that includes all relevant variables (X_i) that impact on productivity and all variables that impact on whether the firm exports or not (Z_i).

Matching is done on the set of variables $W = (X, Z)$, so that any selection on unobservables is assumed to be trivial and does not affect outcomes in the absence of exporting. As Heckman and Navarro-Lozano (2004) point out, this requirement can lead to problems since "…if the analyst has too much information about the decision of who takes treatment, so that $P(W) = 1$ or 0, the method breaks down because people cannot be compared at a common W … (thus) methods for choosing W based on the fit of the model to data on EXP are potentially problematic". Indeed, typically exporting firms are excluded from analysis if they are not 'supported' by comparable firms from the non-exporting population, which can significantly reduce the size of the sub-group of exporters included in the analysis. Thus where there is little 'common support'[93] between the treated and non-treated comparators, matching breaks down. Another

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[92] In terms of Equation (5.15), it is assumed that $E[Y_i^0 | EXP_i = 1] = E[Y_i^0 | EXP_i = 0]$. Thus matching assumes that Y_i^1 and Y_i^0 are independent of EXP_i.

[93] Here an exporter is said to have 'common support' if its propensity score lies between the minimum and the maximum propensity scores for the non-exporting group.

potential issue is that by definition, matching assumes that the effect for the average exporter is the same as the effect for the marginal firm (i.e. the 'treatment on the treated' effect equals the unconditional average treatmnt effect). Heckman and Navarro-Lozano (*op. cit.*) argue that this is an unattractive implication.

In terms of the practical issues faced in any empirical design of matching firms Bryson *et al.* (2002), Imbens (2004) and Zhao (2004) have provided detailed and useful discussions. Here, in estimating the determinants of exporting, the propensity score matching approach is adopted. The model of probability of exporting (*c.f.* Equation (5.12)) is firstly estimated to derive the propensity score, which is again outlined below –

$$P(Export_{it} = 1) = \phi(lnLP_{it-1}, lnAge_{it-1}, Intang_{it-1}, Size_{it-1}, Industry_{it,} Region_{it}) \tag{5.16}$$

Following Girma *et al.* (2004), if P_i is the propensity score of exporting for firm *i* at time *t*, the propensity score matching procedure is then used to find the closest match (using the 'nearest-neighbour' approach) for each exporting firm in terms of the propensity scores from the sub-group of non-exporting firms –

$$\left|P_i - P_j\right| = \min_{k \notin \{Export_k = 0\}} \{P_i - P_j\} \tag{5.17}$$

Having obtained a matched sample of exporters and non-exporters, there are generally two ways to proceed: firstly, the outcome variable (e.g. TFP) can be compared for each matched pair and the average value obtained as a measure of the impact of exporting on TFP. In common with most studies in this field, this approach is not taken here but rather a multivariate model is estimated using the matched data to test the 'learning-by-exporting' hypothesis. This combination of matching and parametric estimation is argued to improve the results obtained from this type of non-experimental evaluation study, as other impacts on the outcome variable are explicitly controlled for (Blundell and Costa Dias, 2000).

A second approach to dealing with self-selection bias is instrumental variable (IV) estimation. To the best of my knowledge, there are very few studies utilising instrumental variable estimation to examine the causality between export and productivity, probably due to the lack of appropriate instruments. If a variable(s) can be found in the set Z_i that affects whether a firm engages in exporting but does not affect the outcome Y_i (i.e. productivity) directly (i.e. Z_i is not completely determined by X_i) then such a variable(s) can be used to instrument for EXP_i and overcome the problem of self-selection[94]. Put another way, such a variable(s) affects the outcome Y_i indirectly since it determines whether a firm exports (which is correlated with Y_i), but it does not need to enter the outcome equation directly (i.e. does not belong to X_i) and is consequently a source of exogenous influence that can be used to identify the causal impact of EXP_i in the model[95]. The main issue with the approach is finding the appropriate instrument(s) that affects the exporting decision but does not directly affect the outcome (other than through its effect on whether to export). As Angrist and Krueger (2001, p.73) point out, "…good instruments often come from detailed knowledge of the economic mechanism and institutions determining the regressor of interest." Blundell *et al.* (2005) note that natural candidates as instruments are time constant factors and/or 'pre-treatment characteristics'.

Another issue with the IV approach is when those exporting firms experience heterogeneous gains from exporting, and where these effects are corrected with the instrument(s). Then the average impact of exporting on those firms that export is no longer estimated and instead the instrumental variable model estimates a Local Average Treatment Effect (LATE), where the localised impact is obtained on those who change their participation status in response to a change in the value of an instrument (*c.f.* Angrist and Imbens, 1995; Heckman, 2000). The LATE approach complicates matters, resulting in different instruments having different impacts (i.e. there is no longer one homogenous 'treatment' effect), but this depends on whether heterogeneity is a major issue when dealing with self-selection bias. If all firms in the population have the

[94] According to Angrist (2001), this also applies to instrumenting dichotomous variables and in this case, EXP_i.

[95] For example, a valid instrument is one that 'forces' a firm into exporting but is not correlated with the factors that determine TFP, even though exporting is correlated with TFP.

same average productivity response to entering overseas markets, as is assumed the case here, the LATE and standard IV approach are equivalent.

In terms of the data available in *FAME*, the likely candidates as instruments are the age of the firm and whether it possesses any intangible assets. Firm age is not usually included in the production function, as the capital stock is presumed to provide an adequate measure of the vintage of the assets used in production. As to intangible assets (such as R&D and advertising spending), the standard approach in the IO literature is followed and it could be assumed that most (sunk cost) investment in intangibles is to overcome existing barriers to entry into new markets (*c.f.* Carlton, 2005); that is, intangible assets feature in Equation (5.12). Evidence in favour of this approach is based on estimating industry-level production functions, where these variables are found to be always statistically insignificant determinants of (real) gross output, having controlled for other covariates in the model, but they are usually highly significant in determining whether the firm sells overseas. Consequently, this model further incorporates the logarithm of age and a dummy variable to indicate whether intangible assets are possessed, as part of the instrument set when estimating the following dynamic panel-data model, allowing for an autoregressive error term –

$$\begin{aligned} lnY_{it} = {} & \beta_0 + \sum_{j=1}^{4}\pi_{1j}x_{jit} + \sum_{j=1}^{4}\pi_{2j}x_{ji,t-1} + \sum_{l=1}^{4}\sum_{j=1}^{4}\pi_{3j}(D_l x_{jit}) + \pi_4 lnY_{i,t-1} \\ & + \sum_{l=2}^{4}\sum_{s=-1}^{1}\gamma_s D_{li,t-s} + \sum_{l=1}^{4}\beta_l D_l + \sum_{n=1}^{11}\delta_n REG_n + \sum_{p=1}^{x}\tau_p IND_p \\ & + \eta_i + t_t + (1-\rho)e_{it} \end{aligned} \tag{5.18}$$

where the subscripts *i* and *t* represent the *i*-th firm and the *t*-th year of observation, respectively; Y represents real gross output; x_1 represents the logarithm of intermediate inputs, m ; x_2 represents the logarithm of capital stock, k ; x_3 represents the logarithm of total employment, e ; x_4 represents a time trend to take account of technical progress, t ; REG_n and IND_p are region and industry dummy variables respectively; and the composite error term has three elements with η_i affecting all observations for the cross-section firm *i*, t_t affecting all firms for time period *t* and e_{it} affecting only firm *i* during period *t*[96].

Importantly, D_l is a set of dummy variables indicating export status, including EXP_{always}, EXP_{never}, EXP_{entry}, EXP_{exit}, EXP_{both} (see Table 5-7 for definitions of these 5 sub-groups). Although D_ι is a constant that defines each sub-group, for the last three sub-groups (ι=3, 4, 5, i.e. EXP_{entry}, EXP_{exit}, EXP_{both}) firm *i* switches into the sub-group at time *t*, and therefore this is denoted by $D_{\iota it}$. The latter variable enters contemporaneously and with a lead and lagged term, to consider whether firms experience a 'learning-by-exporting' effect with time lags.

To allow for potential endogeneity of factor inputs and exporting, Equation (5.18) is estimated using a systems dynamic panel model approach based on the Generalised Method of Moments (GMM) that is available in Stata (Arellano and Bond, 1998). This is sufficiently flexible to allow for both endogenous regressors (through the use of appropriate instruments involving lagged values – in both levels and first differences – of the potentially endogenous variables in the model) and a first-order autoregressive error term. Data are also weighted prior to estimation of Equation (5.18), because of likely problems with endogenous stratification[97] (given the way the sample is drawn from the population) and/or omitted variables.

Thirdly, the standard Heckman two-stage (or control function) model is a widely used approach to dealing with self-selection bias, which is closely linked to the IV approach (see the Appendix to Chapter 3, pp.140-141, for a discussion on the Heckman approach in more detail). This approach begins with a first-stage use of a probit (or logit) estimator to generate first-stage predicted values of the probability of exporting, with the second stage estimation of Equation (5.18) including the sample selectivity correction terms from the first-stage model.

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[96] Note, if e_{it} is serially correlated such that $e_{it} = \rho e_{it-1} + u_{it}$ then u_{it} is uncorrelated with any other part of the model, and $|\rho|<1$ ensures the model converges to a long-run equilibrium (i.e. the variables in the model are cointegrated).

[97] This occurs when the probability of getting in the sample (denoted by *p*) is correlated with one or more of the variables *x* (such as employment size) in the model. Thus *p* is correlated with both *x* and *e* (the error term in Equation (5.18)) such that $E(x|e) \neq 0$ in the sample, and if unweighted regression is used, the estimated parameters are inconsistent (Heckman, 1979; Hausman and Wise, 1981; Magee *et al.*,1998).

That is, if $\hat{P}_{it}$ is the predicted propensity score of exporting for firm *i* at time *t* (*c.f.* Equation (5.12)), then the inverse Mills ratios (or selectivity terms) from this model are give by –

$$\lambda_{0it} = \frac{-\phi(\hat{P}_{it})}{1 - \Phi(\hat{P}_{it})} \quad if\ Export = 0; \quad \lambda_{1it} = \frac{\phi(\hat{P}_{it})}{\Phi(\hat{P}_{it})} \quad if \quad Export = 1 \tag{5.19}$$

These selectivity terms (λ_0 and λ_1) enter Equation (5.18) to control directly for the correlation of the error term in the model determining TFP with the error term in the model determining whether the firm exports or not. Several authors point out the problems associated with the Heckman approach, such as the need for exclusion restrictions otherwise the model may only be identified through the non-linearity of the selectivity parameter included in the second stage equation (Puhani, 2000; Angrist and Krueger, 2001; Smith, 2004).

The last approach considered here for eliminating the bias that arises from self-selection is the difference-in-difference estimator. If information is available for a pre- and post-treatment period (denoted t' and t, respectively), then measuring the impact of treatment can be achieved using an amended version of Equation (5.14) –

$$\left\{E[Y_{it}^{\,1} \middle| EXP_i = 1] - E[Y_{it'}^{0} \middle| EXP_i = 1]\right\} - \left\{E[Y_{it}^{\,0} \middle| EXP_i = 0] - E[Y_{it'}^{0} \middle| EXP_i = 0]\right\} \tag{5.20}$$

where the first term represents the experience of firms who export between ($t - t'$) and the second term is the experience between ($t - t'$) of those not exporting. To justify this difference-in-difference estimator, it is assumed that (in terms of the counterfactual) what exporters would have experienced in the post-entry period, had they not sold overseas, is the same as the experience of non-exporters. That is –

$$\left\{E[Y_{it}^{\,0} \middle| EXP_i = 1] - E[Y_{it'}^{0} \middle| EXP_i = 1]\right\} = \left\{E[Y_{it}^{\,0} \middle| EXP_i = 0] - E[Y_{it'}^{0} \middle| EXP_i = 0]\right\} \tag{5.21}$$

The missing counterfactual is now known since rearranging (5.21) gives –

$$E(Y_{it}^{0}|EXP_i = 1) = E(Y_{it'}^{0}|EXP_i = 1) + \left\{E[Y_{it}{}^{0}|EXP_i = 0] - E[Y_{it'}^{0}|EXP_i = 0]\right\} \qquad \textbf{(5.22)}$$

that is, the outcome that exporters would have experienced post-entry, had they not exported, equals their outcome effect before entry takes place adjusted for what happens over the period to all those not exporting (the last major term in Equation (5.22)).

A major issue with this approach is the assumption underlying equation (5.21), which is needed to justify the difference-in-differences estimator. Essentially it is assumed that the outcome effect for exporters would have been the same as that experienced by non-exporters in the absence of exporting; but this seems unlikely if exporters are a self-selected sub-group exhibiting characteristics that make it more likely they will do better in terms of productivity if they export[98]. Therefore, this method is not adopted here due to its obvious limitations.

In summary, the relationship between exporting and productivity is tested using three approaches to provide more robust results, viz. an IV approach, a control function approach and a matching approach, although *a priori* the IV approach is expected to be superior (since the control function approach is less suitable for panel data and matching is not optimal when the treatment occurs at different points in time).

Lastly, it is worth noting that the Olley and Pakes (1996) model (hereafter denoted OP) has become increasingly popular in recent attempts to test for the learning effects of exporting (e.g. Ackerberg *et al.*, 2005; van Biesebroeck, 2005; and De Loecker, 2007); and thus this part discusses briefly why the above three approaches are chosen instead of this OP method. The OP approach provides an attempt to overcome endogeneity between output and inputs in the production function, while it also incorporates the impact of selectivity effects due to firms that close down (often presumed to be non-exporters, at the lower

[98] For instance, Girma *et al.* (2004) have experienced this problem as they state (p. 863) that "… the reliability of the difference-in-differences methodology is, of course, dependent on the assumption that exporting and non-exporting firms are similarly affected by macro factors that are contemporaneous with entry". They find rather small 'export-by-leaning' effects using a difference-in-differences estimator applied to matched data, but larger effects when using their whole dataset (including the unmatched) leading them to surmise that "…exporting firms respond to exchange rate uncertainties in a different way from non-exporting firms".

end of the productivity distribution). Basically, consider the following Cobb-Douglas value-added production function[99] –

$$y_{it} = \alpha_0 + \alpha_E e_{it} + \alpha_K k_{it} + \omega_{it} + \varepsilon_{it}$$

(5.23)

where y is now value added (rather than gross output) and ω represents productivity shocks that are assumed to be observed by the firm, but not by the econometrician. As it stands, there is endogeneity as $E(e_{it} \mid \omega_{it}) \neq 0$ and $E(k_{it} \mid \omega_{it}) \neq 0$, as the firm's optimal choice of factor inputs will generally be correlated with productivity shocks. OP assume that i) ω evolves exogenously following a first-order Markov process, and in particular does not depend contemporaneously on any of the decision variables for the firm (such as investment and whether to export); ii) e_{it} is a non-dynamic input (i.e. it has no impact on future profits of the firm, thus ruling out training, hiring and firing costs); iii) k_{it} is decided in period $t-1$ (ruling out the use of hired capital assets and/or incremental additions to capital, during t); and iv) the firm's optimal investment, i, is a strictly increasing function of its current productivity, conditional on other state variables which include exporting status in the present context [i.e. $i_{it} = f_t(\omega_{it}, k_{it}, EXP_{it-1})$][100]. Thus the decision on whether to export next period is therefore determined by an analogous policy function – $\Delta EXP_{it} = g_t(\omega_{it}, k_{it}, EXP_{it-1})$, simultaneously with the investment decision, and the current decision to export only affetcts productivity in the following period. Based on assumption iv) the investment function can be inverted to obtain –

$$\omega_{\mathrm{it}} = \mathrm{f}_{\mathrm{t}}^{-1}(\mathrm{i}_{\mathrm{it}}, \mathrm{k}_{\mathrm{it}}, \mathrm{EXP}_{\mathrm{it-1}})$$

(5.24)

and Equation (5.24) can be used to substitute into the production function to control for the unobserved ω_{it} –

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[99] The time trend is dropped from Equation (5.10) for ease of notation (although empirical estimation typically includes time dummies, as well as industry and other relevant dummies to control for shifts in the function). However, the OP approach typically does not include intermediate inputs, although Levinsohn and Petrin (2003) have extended OP to include such inputs.

[100] Note, the firm-invariant function f_t also depends on variables such as input prices and demand, and therefore any inversion – as discussed below – involves "… complicated mapping from states to actions, which have to hold for all firms regardless of their size or competitive position" (van Biesebroeck, 2006, p.12).

$$y_{it} = \alpha_0 + \alpha_E e_{it} + \alpha_K k_{it} + f_t^{-1}(i_{it}, k_{it}, EXP_{it-1}) + \varepsilon_{it}$$

(5.25)

The OP approach then proceeds through three estimation steps, whereby in principle (given the above assumptions), the parameters from the production function can be identified and unbiased estimates obtained. However, this involves using semi-parametric techniques in stage 1, whereby Equation (5.25) is estimated with the composite term $\alpha_K k_{it} + f_t^{-1}(i_{it}, k_{it}, EXP_{it-1})$ replaced by an unknown polynomial involving the three variables involved in this term. More importantly it has been shown by Ackerberg *et al.* (2005) that because of collinearity between $\alpha_K k_{it} + f_t^{-1}(i_{it}, k_{it}, EXP_{it-1})$ and e_{it} it is not possible to identify the parameter α_k. When compared to using a dynamic panel estimator (DPD), Ackerberg *et al.* (*op. cit.*) point out a number of other drawbacks of the OP approach. Firstly, DPD methods can allow for fixed effects (the η_i term in Equation (5.18)), and OP does not, which could lead to substantial bias. Secondly, with respect to Equation (5.24), it has to be assumed that there is strict monotonicity between investment and productivity, and that ω_{it} is the only unobservable input entering the investment function (prior to inversion), ruling out measurement error in these variables. The DPD model does not require such assumptions, and it also allows for weaker assumptions with respect to the error term in the production function (ε_{it} uncorrelated with factor inputs prior to t, whereas OP requires ε_{it} to be uncorrelated at all t). In addition, DPD modelling does not invoke assumptions ii) and iii) above concerning the timing of investment and that labour be a non-dynamic input.

Estimation Results

Turning to the estimation of Equation (5.18), in testing the existence of a learning effect of exporting, all three approaches discussed above are employed. $lnAge_{it}$ and $Intang_{it}$ are included as part of the instrument set when estimating the production function, since these variables are found insignificant themselves when introduced as right-hand-side variables in (5.18) although they are generally important as prior determinants of the likelihood of exporting. The second approach is to include the sample selectivity correction terms λ_0 and λ_1 in Equation (5.18) so as to control directly for the correlation between the error terms in Equations (5.12) and (5.18). This is labelled the ‘control function’ model in the reported results. Lastly, the propensity score matching procedure is employed to obtain a matched sample of exporters and non-exporters based on Equation (5.17), and this matched sample is used when estimating Equation (5.18).

The full set of results from estimating Equation (5.18) are reported in Table 5-15 (in the Appendix). Table 5-15 provides long-run estimates as well as the estimated coefficient on the lagged dependent variable in order to assess the speed of adjustment (i.e. how long it takes to converge on the long-run equilibrium reported), together with the diagnostic tests of the adequacy of the IV model for each industry sub-group. In most cases, the models estimated pass diagnostic tests in terms of autocorrelation (*c.f.* the AR(1) and AR(2) test statistics) and the adequacy of the instrument set used (*c.f.* the Hansen test results)[101].

Here the emphasis is placed upon the variables linked to testing the ‘learning-by-exporting’ effect; nevertheless, it is interesting to note the results in Table 5-15 show that increasing returns-to-scale (henceforth RTS) are generally present for all sub-groups (i.e. 14 industries examined), the average sum of the output elasticities is 1.14 for those firms that have always exported, followed by a value of 1.13 for those moving into exporting; the average RTS for firms never exporting is the lowest at 1.02.

The long-run parameter estimates that refer to the impact of ‘learning-by-exporting’ for the IV, control function and matching models are shown in Table 5-12. There are 3 sets of estimates that consider whether post-entry exporting improves productivity: firstly, there are the terms that show whether firms new to exporting have the expected pattern of significant, positive estimates in *t* and $t+1$ (*c.f.* the EXP_{entry} variables); second, the TFP impacts for those firms leaving exporting are measured with the expectation that (if ‘learning-by-exporting’ is prevalent) there should be significant, negative effects in *t* and *t+1* for firms that exit overseas markets (*c.f.* the EXP_{exit} variables); lastly, the model also

[101] Similar results (in terms of diagnostic statistics and often parameter estimates) are obtained when the ‘control function’ model and the matching model are estimated. Detailed results for these two models are not reported in this thesis but available upon request.

allows for the effect on TFP of those that both enter and leave export markets, with the expectation of significant, positive estimates in *t* and $t+1$ (*c.f.* the EXP_{both} variables).

The results show that generally all three approaches to controlling for selectivity effects produce broadly similar results. The sample selectivity terms (λ_0 and λ_1) are generally insignificant, suggesting that the IV model has adequately controlled for potential selectivity bias. The matching approach results in substantial reduction in the number of observations available in those industries where exporters are in the minority, and the loss of exporters without ‘common support’ in those sectors where the majority of firms do export[102], but the parameter estimates obtained are generally not too different to those obtained using the standard IV approach.

[102] The ‘pstest’ procedure available in Stata is used to inspect the extent of covariate balancing after matching (see Leuven and Sianesi, 2003, for details of this test). In all cases the matched exporter and non-exporter sub-groups have the same mean propensity scores, and there is always a 100% reduction in ‘bias’ with respect to the values of propensity scores in the matched sample.

Table 5-12: Long-run 'learning-by-exporting' effect for certain UK industries, 1996-2004

	AGF	FBT	TCL	WPP	CRR	MET	ENG
IV model (GMM)							
EXP_entry $_{t+1}$	0.061	-0.013	0.066	0.678*	0.242	-0.004	0.112
EXP_entry $_{t}$	-0.012	0.117**	0.173	-0.228	0.030	-0.043	0.278***
EXP_entry $_{t-1}$	-0.066	-0.019	-0.094	-0.238**	0.068	-0.052	-0.215**
EXP_exit $_{t+1}$	0.084	-0.126*	-0.284*	0.107	-0.186*	-0.264***	0.098
EXP_exit $_{t}$	0.133	-0.054	-0.072	0.118	-0.692***	0.120	-0.091
EXP_exit $_{t-1}$	-0.447	-0.049	0.157	-0.236	0.399*	0.237***	-0.114*
EXP_both $_{t+1}$	0.689***	-0.021	-0.086	0.076	-0.025	-0.072	-0.048
EXP_both $_{t}$	0.042	0.211**	-0.153	-0.013	-0.004	0.071	0.036
EXP_both $_{t-1}$	0.260	-0.104*	0.110	0.057	-0.017	-0.008	0.009
No. of Obs.	1702	3065	2223	6903	4629	7075	9596
No. of groups	508	741	530	1798	1107	1719	2252
Control function							
EXP_entry $_{t+1}$	0.074	-0.014	0.013	0.743**	0.256	-0.013	0.094
EXP_entry $_{t}$	-0.061	0.271**	0.298	0.390	-0.041	0.039	0.410*
EXP_entry $_{t-1}$	-0.043	-0.013	-0.157	-0.329***	0.056	-0.065	-0.200*
EXP_exit $_{t+1}$	0.086	-0.108*	-0.272	0.127	-0.181**	-0.198***	0.043
EXP_exit $_{t}$	0.117	-0.257	-0.029	-0.433	-0.476	-0.001	-0.281
EXP_exit $_{t-1}$	-0.383	-0.015	0.174	-0.272**	0.295	0.215***	-0.102*
EXP_both $_{t+1}$	0.693***	-0.054	-0.115	0.056	0.006	-0.053	-0.051
EXP_both $_{t}$	0.018	0.369**	-0.117	0.463**	-0.065	0.118	0.222
EXP_both $_{t-1}$	0.283	-0.158*	0.103	0.035	0.001	-0.010	0.025
λ_1	0.009	-0.014	0.009	-0.201***	0.109	-0.040	0.012
λ_0	0.058	-0.240***	-0.014	0.352	0.015	0.007	-0.122*
No. of Obs.	1702	3065	2223	6903	4629	7075	9596
No. of groups	508	741	530	1798	1107	1719	2252
Matched sample							
EXP_entry $_{t+1}$	0.048	0.020	-0.043	0.533**	0.241*	0.008	0.115
EXP_entry $_{t}$	0.009	0.093**	0.340*	-0.113	-0.001	-0.065	0.276***
EXP_entry $_{t-1}$	0.025	0.001	-0.031	-0.246***	0.082	-0.022	-0.201*
EXP_exit $_{t+1}$	0.036	-0.092*	-0.349*	0.097	-0.192*	-0.281***	0.092
EXP_exit $_{t}$	-0.006	-0.077	0.039	0.120	-0.729***	0.176*	-0.075
EXP_exit $_{t-1}$	-0.415	-0.042	0.200	-0.254*	0.436*	0.212***	-0.106*
EXP_both $_{t+1}$	0.694	-0.040	-0.091	0.086	-0.006	-0.072	-0.039
EXP_both $_{t}$	0.026	0.185**	-0.057	-0.002	0.001	0.070	0.035
EXP_both $_{t-1}$	0.309***	-0.063	0.205	0.064	-0.012	-0.010	-0.006
No. of Obs.	682	2564	2100	5178	4525	6386	3731
No. of groups	261	685	509	1526	1089	1610	948
Characteristics of Industry Group							
Import Penetration (%)	17.13	10.88	18.77	11.22	15.80	10.44	25.57
Export Intensity	0.159	0.189	0.282	0.241	0.578	0.363	0.419
Herfindahl Index	0.052	0.052	0.027	0.036	0.233	0.037	0.079
Intangible assets	0.352	0.453	0.226	0.447	0.645	0.334	0.421

Table 5-12 (cont.)

	OMF	CON	RSM	TRA	POT	FIN	BUS
IV model (GMM)							
EXP_entry $_{t+1}$	-0.094	0.069	0.051	0.122	-0.001	-0.314	-0.260
EXP_entry $_{t}$	0.272***	0.101*	0.065	-0.025	0.135***	0.673***	0.649**
EXP_entry $_{t-1}$	-0.084*	-0.123	0.019	-0.095	0.047	0.106	-0.160
EXP_exit $_{t+1}$	-0.068	0.069	-0.446***	-0.247*	0.102**	-0.267	-0.049
EXP_exit $_{t}$	0.094	-0.151	0.048	0.033	-0.736**	0.115	0.442
EXP_exit $_{t-1}$	0.055	-0.004	0.131*	0.087	0.359	-0.012	0.023
EXP_both $_{t+1}$	-0.045	0.033	0.166	-0.277	0.247	0.235	-0.434
EXP_both $_{t}$	0.042	0.026	0.047	-0.291	0.109	0.542**	0.025
EXP_both $_{t-1}$	-0.055	-0.010	0.078	-0.051	0.063	0.007	-0.284*
No. of Obs.	3731	10531	6094	3229	979	15285	23841
No. of groups	948	3055	1644	1051	337	4655	7932
Control function							
EXP_entry $_{t+1}$	-0.102	0.068	0.144*	0.129	-0.045	-0.682*	-0.037
EXP_entry $_{t}$	0.353	0.300*	-0.366	-0.130	0.139*	1.841***	1.325**
EXP_entry $_{t-1}$	-0.063	0.066	0.171**	-0.110	-0.155	0.025	-0.370
EXP_exit $_{t+1}$	-0.068	0.090	-0.383**	-0.260*	0.104***	-0.226	-0.028
EXP_exit $_{t}$	-0.066	-0.549	0.588	0.319	-0.675**	-0.800	-0.243
EXP_exit $_{t-1}$	0.070	-0.012	0.145	0.092	0.502	-0.032	0.092
EXP_both $_{t+1}$	-0.051	0.019	0.135	-0.018	0.226	0.333	-0.441
EXP_both $_{t}$	0.092	0.424	-0.434	-0.230	1.211	1.582***	0.578
EXP_both $_{t-1}$	-0.045	0.007	0.061	0.282	-0.154	-0.066	-0.378***
λ_1	0.017	-0.122	0.099*	0.042	-0.333*	-0.183*	-0.164
λ_0	-0.121	-1.646	-0.289	-0.534	-0.555	-2.217***	0.314
No. of Obs.	3731	10531	6094	3225	979	15285	23841
No. of groups	948	3055	1644	1050	337	4655	7932
Matched sample							
EXP_entry $_{t+1}$	-0.063	0.085*	0.029	0.101	-0.033	-0.228	-0.202
EXP_entry $_{t}$	0.278***	0.085**	0.076	0.102	0.201**	0.350***	0.303***
EXP_entry $_{t-1}$	-0.136*	-0.102**	0.003	0.015	0.072	0.116	0.003
EXP_exit $_{t+1}$	-0.067	0.016	-0.380***	-0.195**	0.080***	-0.105	0.019
EXP_exit $_{t}$	0.108	-0.142	0.000	0.086	-0.681***	-0.113	0.085
EXP_exit $_{t-1}$	0.052	-0.003	0.093	0.056	0.446	0.019	-0.054
EXP_both $_{t+1}$	-0.058	0.030	0.063	-0.386*	0.156	0.064	-0.166
EXP_both $_{t}$	0.038	0.027	-0.037	-0.087	0.141	0.430**	0.091
EXP_both $_{t-1}$	-0.088	-0.011	-0.038	-0.010	0.105	0.029	-0.168*
No. of Obs.	3443	2941	1326	1301	666	3992	16164
No. of groups	890	1338	659	623	266	1807	5911
Characteristics of Industry Group							
Import Penetration (%)	12.62	0.09	0.48	8.00	3.91	1.91	4.91
Export Intensity	0.261	0.072	0.093	0.213	0.163	0.124	0.242
Herfindahl Index	0.037	0.004	0.007	0.074	0.116	0.033	0.013
Intangible assets	0.336	0.239	0.288	0.371	0.553	0.323	0.491

Notes: The 2-step GMM system estimator in Stata is used using weighted *FAME* data. Standard errors are obtained using the ‘delta’ method. ***/**/* significant at the 1%/5%/10% level.

Table 5-12 shows that ‘learning-by-exporting’ is present but it is by no means universal, and even within industry groups there are differences for entrants, exiting exporters and those that experience both entry and exit into overseas markets. Based on the review of the literature in Chapter 4, stronger effects are more likely when the country exporting has a smaller market size with less intense internal competition and when there is scope for catching-up with international best practices (*c.f.* Baldwin and Gu, 2004); when there is higher industry exposure to exporting (and presumably by implication higher import penetration), bringing firms into contact with better technology and business practices (*c.f.* Greenaway and Kneller, 2007); and when firms invest in resources and capabilities that enhance their ability to learn and absorb new ideas and practices, and thus compete effectively in overseas markets (*c.f.* Crespi *et al.*, 2008). The last four rows in Table 5-12 show for each industry group the average import penetration over the period 1996-2004; export intensity (overseas sales as a proportion of total output); industry concentration (based on the Herfindahl index); and the proportion of firm in the industry with non-zero intangible assets (definitions of the variables are provided in Table 5-7). An overall 'learning-by-exporting' effect is then calculated for each of the 14 industry groups, based on summing the significant parameter estimates in Table 5-12 (using positive values when the sign on the coefficient is consistent with a 'learning' effect, and negative values when the sign has the 'wrong' value). To gauge if there is any linear association between the 'learning-by-exporting' effect across industries and the above variables, all data are logged and (pearson) correlation coefficients calculated; it is found (omitting the financial services sector as an outlier amongst the 14 industries considered) that the correlation between 'learning-by-exporting' and import penetration, export intensity, the Herfindalhl index and the proportion of firms with positive intangible assets is 0.48 (0.05), 0.45 (0.06), 0.49 (0.4) and 0.77 (0.01), respectively (significance levels, based on a one-tailed test, are reported in parentheses). While these results are only indicative[103], they do lend support to the findings in the literature that firms that are exposed to greater globalisation effects, that have the ability to internalise the benefits of such exposure, and that are large enough to be less affected by domestic competition (and thus presumably have scope to take on greater risk

[103] Correlations are only reported to provide an indication of patterns in the data, for the industry groups covered. More detailed analysis of the causes of the 'learning-by-exporting' effect is beyond the scope of this thesis. Note, the average age of firms and the proportion that exports are also included when conducting the correlation analysis; the former was highly insignificant, while the latter was only significant at the 14% level.

and uncertainty associated with internationalisation), are all more likely to experience additional productivity premiums post-entry into export markets.

To further summarise the results obtained, those parameter values that are significant (at the 10% level or better) are weighted by their shares in total (real) gross output to obtain an overall estimate for the UK economy. Overall, the results in Table 5-13 show that there is a fairly substantial post-entry productivity effect for firms that are new to exporting (e.g. based on the IV model, a 34% long-run increase in TFP in the year of entry, and only a small effect of around 2% in the year following entry); firms exiting overseas markets overall experience negative productivity effects in the year they exit and subsequently (around 7-8% on average for the economy); while firms that enter and then exit experience large productivity gains whilst exporting (some 19% in the year of entry, but with a 5% decline the following year).

Table 5-13: Average 'learning-by-exporting' effect, UK 1996-2004

	Weighted average all industries [a]
IV model	
EXP_entry $_{t+1}$	0.022
EXP_entry $_{t}$	0.343
EXP_entry $_{t-1}$	-0.026
EXP_exit $_{t+1}$	-0.085
EXP_exit $_{t}$	-0.073
EXP_exit $_{t-1}$	0.032
EXP_both $_{t+1}$	-0.047
EXP_both $_{t}$	0.186
EXP_both $_{t-1}$	-0.038
Control function	
EXP_entry $_{t+1}$	-0.171
EXP_entry $_{t}$	0.839
EXP_entry $_{t-1}$	-0.011
EXP_exit $_{t+1}$	-0.074
EXP_exit $_{t}$	-0.056
EXP_exit $_{t-1}$	0.012
EXP_both $_{t+1}$	0.005
EXP_both $_{t}$	0.553
EXP_both $_{t-1}$	-0.051
Matched sample	
EXP_entry $_{t+1}$	0.040
EXP_entry $_{t}$	0.197
EXP_entry $_{t-1}$	-0.027
EXP_exit $_{t+1}$	-0.076
EXP_exit $_{t}$	-0.068
EXP_exit $_{t-1}$	0.022
EXP_both $_{t+1}$	-0.021
EXP_both $_{t}$	0.149
EXP_both $_{t-1}$	0.050

[a] Average of all estimates in Table 4 that are significant at the 10% or better level (weighted by industry shares of total real gross output in all industries).

The results presented here differ in both approach and outcome to those found in other UK studies. Besides weighting the data to ensure it is representative of the population of firms, and having a more extensive dataset (in terms of the number of observations and industries covered), a dynamic GMM systems approach is also used to directly estimating TFP within a production function model that attempts to control for both sample selection and endogeneity.

In particular, the methodology and findings presented in this chapter differ in several important aspects from another UK study by Girma *et al.* (2004), who use unweighted matched data and a difference-in-differences approach. Above all, as a robustness check, all 14 industry sub-groups have been re-estimated using the IV approach using the unweighted data. The resutls show that generally this leads to lower estimates of ‘learning-by-exporting’ (i.e. parameter estimates have lower values and/or are generally less statistically significant). This may in part explain the lower ‘learning’ effects reported in Girma *et al.* (*op. cit.*). Secondly, their dependent variable is the growth of output (ΔlnY_{it}), or productivity, depending on the different specifications they use. Such a model cannot provide an estimate of the long-run impact of exporting on productivity levels, as long-run impacts by definition are omitted. This is not a trivial issue, as Equation (5.18) used here encompasses both short- and long-run impacts. Moreover, perhaps most importantly, their TFP is obtained using a growth accounting model and thus there is no direct estimation of an economic model where causality can be consistently dealt with (refer to the discussion of the drawbacks of this approach on pp.186-188). Lastly, constraining the underlying production function to exhibit constant returns-to-scale is likely to further bias any estimates of the exporting-productivity relationship, as the exporting variable(s) in the model have to absorb some of the size effect – see van Biesebroeck (2005, Section 5) for evidence on this. Nevertheless, Girma *et al.* (*op. cit.*) do show that the short-run impact of ‘learning-by-exporting’ on growth is important albeit generally quite small.

The results obtained here are also consistent with those in Bernard and Jensen (2004b); they find that in US manufacturing new entrants into export markets are rewarded with a surge in TFP especially during the first year post entry, and thereafter their productivity path becomes flatter, following that of continuous exporters (although with significantly lower productivity levels). In contrast, those that exit from exporting are characterised by a substantial deterioration in productivity to eventually resemble the flat growth trajectory of continuous non-exporters.

The aggregate results for the ‘control function’ model in Table 5-13 tend to be larger, after including the sample selectivity correction terms, while the results for the matched sample are generally lower than those obtained using the standard IV GMM model. Thus, there is some uncertainty as to the overall size of the 'learning-by-exporting' effect, although the results obtained show that nonetheless this effect was present and important to UK firms during 1996-2004.

5.4 Conclusions

As a major contribution of this empirical chapter, as opposed to previous studies, a weighted *FAME* database is employed to obtain a distribution representative of the population of firms operating in the UK, covering all the main marketed output sectors of the economy. The first part of this chapter begins with a description of differences in productivity levels (both labour and TFP) between exporters and non-exporters. Based on average productivity, such analysis shows that firms that always export are most productive, followed by intermittent exporters, and lastly (often at a significantly lower level) those firms always serving domestic market. Separately identifying foreign-owned firms (both exporting and non-exporting) produces a slightly different picture: foreign-owned exporters enjoy the highest productivity, followed in terms of ranking by foreign-owned non-exporters. This implies that foreign-owned firms operating in the UK are less useful as a comparator sub-group when considering whether exporters have relatively higher productivity, since non-exporting foreign firms have productivity advantages that do not necessarily stem from exporting to overseas markets. Based on these results, *inter alia*, foreign-owned firms have been omitted in subsequent econometric modelling.

Applying more powerful testing procedures, statistical analyses that follow test whether productivity distributions (rather than merely mean values) of various sub-groups are indeed different, on an industry-by-industry basis. Results show that firstly, in every industry examined firms that export have a TFP distribution that lies significantly to the right of non-exporters, with the largest difference between the two distributions often being substantial. Secondly, there is evidence that the distribution of TFP for permanent exporters dominates that for firms that have never exported.

Moreover, there is also a discussion on the methodological issues relating to modelling TFP: TFP is best measured using a production function approach that includes the determinants of TFP (such as exporting) directly as part of the model, rather than using a growth accounting approach which (in addition to imposing untested and likely incorrect restrictions) requires a second stage model to estimate the determinants of TFP. It has been argued that using a second-stage model results in both i) inefficient estimates (potentially inconsistent standard errors and hence inconsistent t-values) of the determinants of TFP; and ii) potentially biased estimates since by initially omitting factors from the model that determine output, estimates of TFP are biased due to being incorrectly measured.

The next part of this chapter then discusses in some detail the problem of sample selectivity bias that needs to be dealt with when attempting to test whether firms that export benefit from a 'learning-by-exporting' effect. It is noted that if firms enter export markets independent of (say) their potential productivity gains from exporting, then any potential bias would be zero. However, this seems unrealistic because selection into overseas markets is likely to be made taking account of the potential productivity effects of exporting, and it might be expected that those most likely to benefit will have a higher probability of breaking down barriers to exporting (and indeed other barriers to higher productivity). Put another way, selection bias occurs because the characteristics of the exporters are such that they achieve better performance than non-exporters even when they do not export, and this 'better performance' is correlated with the decision to export.

Various approaches that attempt to eliminate selectivity bias are then discussed. The first is matching, which involves matching every exporting firm with another firm that has (very) similar characteristics but does not export. The propensity score approach is proposed, along with a discussion of its strengths and limitations. The second approach to dealing with self-selection bias is instrumental variable (IV) estimation. The main issue with the IV approach is finding appropriate instrument(s) and in terms of the data available in *FAME*, the likely candidates are the age of the firm and whether it possesses any non-zero intangible assets. This is confirmed when estimating industry-level production functions, where these variables are found to be always statistically insignificant determinants of (real) gross output, but usually highly statistically significant as determinants of exporting. The standard Heckman two-stage (or control function) approach is the last approach to dealing with self-selection bias that is considered. This approach begins with a first-stage use of a probit (or logit) estimator to generate first-stage predicted values of the probability of exporting, with the second stage estimation of the production function including the sample selectivity correction terms from the first-stage model. These selectivity terms are a means to control directly for the correlation of the error term in the model determining TFP with the error term in the model determining whether the firm exports or not.

In terms of modelling results, the first set of results for 14 separate UK industry groups are from estimating probit models determining which firms exported at any time during 1996-2004. Confirming what most all other similar studies have reported in the literature on self-selectivity, these results show that with higher (labour) productivity in period t-1, firms are significantly more likely to sell overseas in period t, although the strength of this relationship varies across industry groups with generally the impact of higher productivity on the probability of exporting being higher in the manufacturing sector. In addition, confirming the importance of resources and capacities, firms with non-zero intangible assets are found to be generally much more likely to export (which again points to a need to invest in highly productive resources that lead to a greater ability to internalise external knowledge in order to overcome barriers to exporting). Lastly, the age of the firm in t-1 is also found to be a major determinant of exporting, supporting process-based incremental models of internationalisation.

Having found strong self-selection by UK firms during 1996-2004, the chapter moves onto testing (using the three approaches to combating self-selectivity discussed above) whether there is a ‘learning-by-exporting’ effect associated with post-entry sales to overseas markets. The results show that generally all three approaches to controlling for selectivity effects have produced broadly similar results. For example, the sample selectivity terms are generally insignificant, suggesting that the IV model has adequately controlled for potential selectivity bias. The matching approach results in substantial reductions in the number of observations available in those industries where exporters are in the minority, and the loss of exporters without ‘common support’ in those sectors are the majority of firms that do export, but the parameter estimates obtained generally do not differ much to those obtained using the standard IV approach.

On balance, findings suggest that ‘learning-by-exporting’ is present but it is by no means universal, and even within industry groups there are differences for entrants into exporting, firms that leave exporting, and those that experience both entry and exit into overseas markets. However, in terms of the overall estimate for the UK economy, the results confirm a fairly substantial post-entry productivity effect for firms new to exporting (based on the IV model, a 34% long-run increase in TFP in the year of entry, and only a small effect of around 5% in the year following entry); firms exiting overseas markets overall experience negative productivity effects in the year they leave and subsequently (around 7-8% on average for the economy); while firms that have both entered and exited experience large productivity gains during their exporting years (some 19% in the year of entry, but with a 5% decline the following year).

Appendix

Full Results of the Exporting-Productivity Modelling

Table 5-14: Proportion of UK firms exporting in different industries, 1996-2004

Industry (2003 SIC group/SIC code)	Proportion of firms exporting
Hotels/restaurants (H; SIC55)	0.005[a]
Real estate (K pt; SIC70)	0.022[a]
Renting (K pt; SIC71)	0.034[a]
Construction (F; SIC45)	0.055[a]
Retail trade (G pt; SIC52)	0.066[a]
Repair/sale motors (G pt; SIC50)	0.088[a]
Wood products (DD; SIC20)	0.092[a]
Post/Telecoms (I pt; SIC64)	0.101[b]
Transport services (I pt; SIC60-62)	0.104[b]
Support for Transport (I pt; SIC63)	0.141[b]
Financial intermediation (J; SIC65-67)	0.157[b]
Computer services/R&D (K pt; SIC72-73)	0.186[b]
Other Business services (K pt; SIC74)	0.187[b]
Food/Beverages/Tobacco (DA; SIC15-16)	0.208[b]
Paper/Printing (DE; SIC21-22)	0.236[b]
Agriculture/Forestry/Fish (A/B; SIC01-05)	0.240[b]
Non-metal minerals (DI; SIC26)	0.255[b]
Wholesale trade (G pt; SIC5121-5190)	0.367[c]
Manufacturing nec (DN; SIC36)	0.383[c]
Fabricated metals (DJ pt; SIC28)	0.449[c]
Textiles/Cloth/Leather (DB/DC; SIC17-19)	0.507[c]
Motor vehicles/parts (DM pt; SIC34)	0.532[c]
Rubber/Plastics (DH; SIC25)	0.554[c]
Electrical machinery (DI pt; SIC31)	0.572[c]
Basic metals/fabricated (DJ; SIC27)	0.612[c]
Other transport (DM pt; SIC35)	0.651[c]
Machinery/Equipment (DK; SIC29)	0.663[c]
Medical/Precision (DI pt; SIC33)	0.741[c]
Office equip/Radio, TV (DI pt; SIC30, 32)	0.746[c]
Coke/Chemicals (DF/DG; SIC23-24)	0.798[c]
Total	0.123

[a] <10% of firms in industry export; [b] 10-30% of firms in industry export; [c] >30% of firms in industry export. Source: calculations based on weighted *FAME*.

Table 5-15: Weighted systems GMM production function long-run estimates, UK 1996-2004 (*c.f.* Equation (5.18))

Industries / Independent variables	AGF		FBT		TCL		WPP	
	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat
ln gross output$_{t-1}$	0.191	1.84	0.062	0.	0.230	2.	0.159	1.
ln M x EXP_always	1.010	4.13	0.686	4.	0.848	6.	0.803	4.
ln M x EXP_never	0.423	5.15	0.696	21.	0.433	18.	0.606	5.
ln M x EXP_entry	0.939	4.48	0.675	5.	0.841	7.	0.519	3.
ln M x EXP_exit	0.523	1.98	0.874	12.	0.635	8.	0.539	3.
ln M x EXP_both	1.142	1.94	0.553	7.	0.804	7.	0.488	3.
ln K x EXP_always	0.102	2.14	0.113	3.	0.119	2.	0.151	2.
ln K x EXP_never	0.155	2.52	0.170	4.	0.179	3.	0.245	2.
ln K x EXP_entry	0.048	1.89	0.066	2.	0.161	2.	0.225	2.
ln K x EXP_exit	0.420	1.90	0.112	1.	0.142	2.	0.269	2.
ln K x EXP_both	0.106	1.06	0.272	3.	0.144	1.	0.248	2.
ln E x EXP_always	0.049	2.87	0.268	2.	0.160	2.	0.148	3.
ln E x EXP_never	0.200	3.00	0.216	4.	0.189	2.	0.296	3.
ln E x EXP_entry	0.089	2.03	0.475	4.	0.074	2.	0.338	3.
ln E x EXP_exit	0.150	2.77	0.130	4.	0.190	2.	0.218	1.
ln E x EXP_both	0.188	2.98	0.207	3.	0.095	1.	0.296	2.
t x EXP_both	0.134	3.07	0.039	2.	0.004	0.	0.030	1.
t x EXP_never	0.016	1.54	0.006	1.	0.004	0.	0.004	0.
t x EXP_entry	0.023	0.61	-0.014	-1.	-0.023	-0.	0.004	0.
t x EXP_exit	0.013	0.12	0.026	1.	0.039	0.	0.025	1.
t x EXP_always	-0.005	-0.38	0.006	1.	-0.003	-0.	-0.021	-1.
EXP_entry $_{t+1}$	0.061	0.99	-0.013	-0.	0.066	0.	0.678	1.
EXP_entry $_{t}$	-0.012	-0.16	0.117	2.	0.173	0.	-0.228	-0.
EXP_entry $_{t-1}$	-0.066	-0.71	-0.019	-0.	-0.094	-1.	-0.238	-1.
EXP_exit $_{t+1}$	0.084	0.67	-0.126	-1.	-0.284	-1.	0.107	0.
EXP_exit $_{t}$	0.133	0.45	-0.054	-0.	-0.072	-0.	0.118	0.
EXP_exit $_{t-1}$	-0.447	-0.53	-0.049	-1.	0.157	1.	-0.236	-1.
EXP_both $_{t+1}$	0.689	4.66	-0.021	-0.	-0.086	-1.	0.076	0.
EXP_both $_{t}$	0.042	0.33	0.211	2.	-0.153	-1.	-0.013	-0.
EXP_both $_{t-1}$	0.260	1.42	-0.104	-1.	0.110	0.	0.057	1.
Constant x EXP_always	1.281	1.05	2.344	2.	-0.628	-0.	1.548	0.
Constant x EXP_never	1.122	0.89	-0.884	-1.	2.535	3.	-0.705	-0.
Constant x EXP_entry	0.001	0.00	-0.261	-0.	0.103	0.	0.716	0.
Constant x EXP_exit	0.272	0.07	-1.085	-1.	1.427	1.	0.249	0.
Constant x EXP_both	-4.562	-0.73	-1.557	-1.	0.500	0.	1.793	0.
Industry dummies	yes		yes		yes		yes	
Region dummies	yes		yes		yes		yes	
Diagnostic statistics								
No. of Obs.	1702		3065		2223		6903	
No. of groups	508		741		530		1798	
Hansen-test (χ^2)	107.15		185.96		150.91		265.83	
AR(1) z-statistic	-3.24***		0.095*		-2.29**		-2.91***	
AR(2) z-statistic	1.08		0.738		1.48		-0.76	

Table 5-15 (cont.)

Industries / Independent variables	CRR		MET		ENG		OMF	
	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat	$\hat{\beta}$	*t*-stat
ln gross output$_{t-1}$	0.194	3.32	0.238	3.	0.165	1.	0.136	1.
ln M x EXP_always	0.739	4.91	0.857	3.44	0.676	4.71	0.785	5.67
ln M x EXP_never	0.794	8.52	0.797	12.04	0.637	10.53	0.783	10.69
ln M x EXP_entry	0.779	5.18	0.827	12.17	0.805	15.15	0.907	21.24
ln M x EXP_exit	0.774	9.36	0.962	12.23	0.916	8.04	0.776	7.13
ln M x EXP_both	0.865	14.11	0.575	3.84	0.543	6.99	0.714	7.67
ln K x EXP_always	0.201	4.67	0.104	2.34	0.169	2.95	0.133	2.11
ln K x EXP_never	0.217	4.88	0.114	2.50	0.113	2.24	0.221	4.43
ln K x EXP_entry	0.116	5.30	0.045	1.85	0.051	2.20	0.127	2.43
ln K x EXP_exit	0.183	4.45	0.048	1.91	0.095	2.02	0.129	2.40
ln K x EXP_both	0.095	3.92	0.172	3.50	0.109	1.86	0.225	4.47
ln E x EXP_always	0.211	2.78	0.097	2.37	0.088	3.00	0.190	2.23
ln E x EXP_never	0.062	2.38	0.158	2.89	0.261	2.65	0.062	3.65
ln E x EXP_entry	0.320	5.31	0.242	3.58	0.283	4.34	0.166	2.96
ln E x EXP_exit	0.139	2.43	0.165	2.49	0.120	1.54	0.206	2.50
ln E x EXP_both	0.253	4.89	0.165	1.99	0.446	4.20	0.094	2.92
t x EXP_both	-0.011	-0.56	-0.042	-2.23	0.022	1.81	0.006	0.26
t x EXP_never	0.004	0.39	-0.005	-0.76	-0.009	-1.09	-0.036	-2.01
t x EXP_entry	-0.019	-0.63	0.017	1.40	0.002	0.14	-0.004	-0.31
t x EXP_exit	0.044	2.55	-0.010	-0.50	-0.006	-0.27	-0.002	-0.09
t x EXP_always	0.008	1.55	-0.002	-0.23	0.005	0.66	-0.007	-1.12
EXP_entry $_{t+1}$	0.242	1.58	-0.004	-0.06	0.112	1.50	-0.094	-1.02
EXP_entry $_{t}$	0.030	0.22	-0.043	-0.61	0.278	2.62	0.272	3.12
EXP_entry $_{t-1}$	0.068	1.29	-0.052	-0.84	-0.215	-2.01	-0.084	-1.80
EXP_exit $_{t+1}$	-0.186	-1.88	-0.264	-3.72	0.098	1.27	-0.068	-0.69
EXP_exit $_{t}$	-0.692	-3.26	0.120	1.30	-0.091	-0.73	0.094	0.70
EXP_exit $_{t-1}$	0.399	1.76	0.237	4.24	-0.114	-1.82	0.055	0.52
EXP_both $_{t+1}$	-0.025	-0.33	-0.072	-0.93	-0.048	-0.66	-0.045	-0.86
EXP_both $_{t}$	-0.004	-0.20	0.071	0.97	0.036	0.60	0.042	0.51
EXP_both $_{t-1}$	-0.017	-0.22	-0.008	-0.18	0.009	0.17	-0.055	-1.34
Constant x EXP_always	0.924	1.75	0.834	0.80	1.634	3.01	0.849	0.71
Constant x EXP_never	0.338	0.55	0.189	0.16	0.471	0.78	0.284	0.21
Constant x EXP_entry	0.147	0.20	0.399	0.37	-0.155	-0.24	-0.969	-0.83
Constant x EXP_exit	0.621	1.01	-0.020	-0.02	-0.756	-1.05	-0.081	-0.06
Constant x EXP_both	0.352	0.62	2.959	2.32	0.411	0.78	0.349	0.31
Industry dummies	yes		yes		yes		yes	
Region dummies	yes		yes		yes		yes	
Diagnostic statistics								
No. of Obs.	4629		7075		9596		3731	
No. of groups	1107		1719		2252		948	
Hansen-test (χ^2)	230.23		324.10		311.20		212.36	
AR(1) z-statistic	-1.95*		-2.69***		-2.77***		-1.23	
AR(2) z-statistic	0.49		-0.87		-1.16		-0.91	

Table 5-15 (cont.)

Independent variables \ Industries	CON $\hat{\beta}$	CON *t*-stat	RSM $\hat{\beta}$	RSM *t*-stat	TRA $\hat{\beta}$	TRA *t*-stat
ln gross output$_{t-1}$	0.038	0.58	0.398	4.49	0.467	3.22
ln M x EXP_always	0.691	5.64	0.823	4.66	0.878	2.94
ln M x EXP_never	0.799	15.93	0.729	10.20	0.609	9.33
ln M x EXP_entry	0.898	19.43	0.914	31.09	0.766	7.64
ln M x EXP_exit	0.635	5.17	0.872	20.66	0.698	8.91
ln M x EXP_both	0.951	24.15	0.867	11.88	0.252	2.37
ln K x EXP_always	0.229	2.99	0.121	2.05	0.132	2.35
ln K x EXP_never	0.159	2.55	0.102	2.27	0.071	2.04
ln K x EXP_entry	0.124	2.05	0.073	2.05	0.136	1.90
ln K x EXP_exit	0.141	2.73	0.049	2.17	0.126	1.82
ln K x EXP_both	0.162	2.46	0.022	1.68	0.042	1.61
ln E x EXP_always	0.171	2.23	0.263	2.99	0.209	2.83
ln E x EXP_never	0.161	2.68	0.182	3.86	0.198	2.41
ln E x EXP_entry	0.119	2.22	0.058	2.03	0.090	3.28
ln E x EXP_exit	0.446	3.66	0.088	2.55	0.148	3.55
ln E x EXP_both	0.049	1.99	0.208	2.13	0.410	3.51
t x EXP_both	0.014	2.44	-0.001	-0.08	-0.103	-0.78
t x EXP_never	-0.004	-0.85	0.000	0.01	0.007	1.02
t x EXP_entry	0.008	0.38	-0.015	-0.54	0.048	1.50
t x EXP_exit	-0.044	-1.67	0.010	0.34	0.046	1.88
t x EXP_always	-0.021	-1.36	-0.004	-0.16	-0.011	-0.34
EXP_entry $_{t+1}$	0.069	1.34	0.051	0.76	0.122	0.99
EXP_entry $_{t}$	0.101	1.95	0.065	0.79	-0.025	-0.41
EXP_entry $_{t-1}$	-0.123	-1.59	0.019	0.29	-0.095	-0.95
EXP_exit $_{t+1}$	0.069	0.58	-0.446	-3.68	-0.247	-1.86
EXP_exit $_{t}$	-0.151	-1.12	0.048	0.51	0.033	0.24
EXP_exit $_{t-1}$	-0.004	-0.05	0.131	1.82	0.087	0.80
EXP_both $_{t+1}$	0.033	1.17	0.166	1.40	-0.277	-0.53
EXP_both $_{t}$	0.026	0.96	0.047	0.46	-0.291	-0.74
EXP_both $_{t-1}$	-0.010	-0.42	0.078	1.04	-0.051	-0.13
Constant x EXP_always	1.520	3.46	0.660	0.82	-0.856	-0.38
Constant x EXP_never	-0.180	-0.35	1.032	1.16	2.292	0.99
Constant x EXP_entry	-0.425	-0.54	0.213	0.25	1.299	0.59
Constant x EXP_exit	0.455	0.51	0.791	0.89	1.366	0.58
Constant x EXP_both	-1.090	-2.06	0.394	0.37	5.325	0.53
Industry dummies	yes		yes		yes	
Region dummies	yes		yes		yes	
Diagnostic statistics						
No. of Obs.	10531		6094		3229	
No. of groups	3055		1644		1051	
Hansen-test (χ^2)	295.22		167.54		91.40	
AR(1) z-statistic	-2.74^{***}		-2.05^{**}		-1.30	
AR(2) z-statistic	1.93^{*}		-0.66		-1.97^{**}	

Table 5-15 (cont.)

Industries / Independent variables	POT $\hat{\beta}$	POT *t*-stat	FIN $\hat{\beta}$	FIN *t*-stat	BUS $\hat{\beta}$	BUS *t*-stat
ln gross output$_{t-1}$	0.225	2.70	0.631	5.20	0.416	6.59
ln M x EXP_always	0.716	5.07	0.932	4.40	0.759	3.87
ln M x EXP_never	0.769	14.76	0.453	6.66	0.846	7.63
ln M x EXP_entry	0.501	4.59	0.293	2.46	0.749	4.72
ln M x EXP_exit	0.415	2.75	0.430	2.69	0.560	2.62
ln M x EXP_both	0.124	2.56	0.187	1.93	0.468	2.51
ln K x EXP_always	0.119	2.35	0.090	2.14	0.171	2.34
ln K x EXP_never	0.138	2.34	0.096	2.55	0.025	2.28
ln K x EXP_entry	0.234	3.90	0.150	2.68	0.062	3.24
ln K x EXP_exit	0.106	2.11	0.304	3.27	0.165	1.63
ln K x EXP_both	0.249	1.88	0.160	1.88	0.219	2.44
ln E x EXP_always	0.339	2.63	0.244	2.44	0.122	2.31
ln E x EXP_never	0.134	2.41	0.440	2.94	0.298	2.85
ln E x EXP_entry	0.305	3.28	0.651	3.55	0.370	2.33
ln E x EXP_exit	0.776	4.55	0.363	2.00	0.411	2.34
ln E x EXP_both	0.641	2.81	0.677	3.61	0.396	2.17
t x EXP_both	0.016	0.17	0.036	0.72	0.025	0.62
t x EXP_never	-0.030	-1.50	-0.003	-0.56	-0.008	-0.54
t x EXP_entry	0.138	2.67	-0.010	-0.13	-0.048	-0.63
t x EXP_exit	0.098	0.47	-0.030	-0.40	-0.039	-0.94
t x EXP_always	-0.068	-1.27	-0.005	-0.30	0.010	0.44
EXP_entry $_{t+1}$	-0.001	0.00	-0.314	-1.48	-0.260	-0.44
EXP_entry $_{t}$	0.135	2.61	0.673	3.22	0.649	2.51
EXP_entry $_{t-1}$	0.047	0.40	0.106	0.46	-0.160	-0.45
EXP_exit $_{t+1}$	0.102	2.40	-0.267	-1.00	-0.049	-0.29
EXP_exit $_{t}$	-0.736	-2.24	0.115	0.35	0.442	0.87
EXP_exit $_{t-1}$	0.359	0.92	-0.012	-0.06	0.023	0.11
EXP_both $_{t+1}$	0.247	0.61	0.235	0.71	-0.434	-1.43
EXP_both $_{t}$	0.109	0.37	0.542	2.11	0.025	0.14
EXP_both $_{t-1}$	0.063	0.34	0.007	0.04	-0.284	-1.68
Constant x EXP_always	0.856	0.45	0.620	0.59	2.735	1.66
Constant x EXP_never	0.120	0.06	1.862	1.65	-2.153	-1.16
Constant x EXP_entry	-0.520	-0.26	1.227	0.98	0.312	0.16
Constant x EXP_exit	2.607	1.14	1.722	1.23	0.936	0.39
Constant x EXP_both	1.438	0.55	1.015	0.77	1.686	0.98
Industry dummies	yes		yes		yes	
Region dummies	yes		yes		yes	
Diagnostic statistics						
No. of Obs.	979		15285		23841	
No. of groups	337		4655		7932	
Hansen-test (χ^2)	129.89		359.54*		334.72	
AR(1) z-statistic	-1.45		-6.18***		-6.19***	
AR(2) z-statistic	-1.09		-0.04		-0.25	

Notes: 2-step GMM system estimator in Stata is used (i.e. ‘xtabond2’); standard errors of the long-run estimates are calculated using the ‘delta’ method; the instrument set includes lagged values of the RHS variables in the model as well as age and intangible assets. $^{***}/^{**}/^{*}$ significant at the 1%/5%/10% level.

Chapter 6: The Relationship between R&D Capital Stock and Productivity

6.1 The Productivity Impact of Innovation and Measurement Issues

The innovation-productivity relationship encompasses both the productivity impact of innovation undertaken within individual firms as well as the productivity effects of other firms' innovative activities, i.e. knowledge spillovers. Earlier surveys of the well-established literature on spillovers date back to Cameron (1966) and Griliches (1992). Centring on the themes of resource base and knowledge generation, this thesis is particularly concerned with how the availability of knowledge outside the firm can impact on knowledge creation (e.g. in terms of R&D activity) within individual firms (refer to Chapter 2, pp.49-54, for more discussion on knowledge spillovers and the related spatial factors as determinants of business innovation). There are various forms of external knowledge that may spillover to the benefit of firms, which may not be specifically linked to innovation. Thus, knowledge spillovers can be derived from a wide range of factors that potentially arise from firms interacting with the environment, and this complicates what is meant by knowledge spillovers and how they benefit the firm (e.g. technical know-how, or something more abstract and harder to define/measure).

Nevertheless, given the particular interest of this thesis, the focus here is on the form of external knowledge that may not be totally appropriated by individual firms, i.e. the external innovative activity undertaken by other firms or by the public sector; such spending on external innovation can therefore impact directly on an individual firm's own innovation activity and thus consequently impact on its productivity/performance. That is, the firm conducts innovative activity presumably to produce its own internal knowledge that may directly lead to tangible innovation outcomes and thus improvements in productivity, whereas there is also an indirect effect of (internal and external) innovation on productivity that is not specifically linked to innovation outputs (such as new products and processes) but rather, as a by-product, the firm reaps the more general benefits of engaging in innovative processes such as greater absorptive capacity.

6.1.1 The 'Knowledge Production Function' (KPF) Approach

This innovation-productivity relationship is usually examined empirically using R&D-based innovation measures. There are two main strands to the micro-based literature on the impact of R&D activity on firm-level productivity. Above all, the most widely used methodology to estimating the R&D-productivity relationship is based on the notion of the 'knowledge production function' (henceforth KPF) as developed by Griliches (1980), whereby a simple Cobb-Douglas production function is extended to include the R&D capital stock of the firm (and in some studies, of other firms, to capture spillover effects). The advantage of such a KPF formulation lies in its straightforward representation of the transformation process running from innovative inputs to outputs. An extensive review of the literature on the KPF modelling has been recently provided in Wieser (2005), which often starts with the following log-linear version of the Cobb-Douglas production function –

$$y_{it} = \alpha + \beta_1 k_{it} + \beta_2 n_{it} + \beta_3 m_{it} + \beta_4 rd_{it} + \beta_5 ex\_rd_{it} + \lambda t + \upsilon_{it} \quad \textbf{(6.1)}$$

where lower-case terms denote (natural) logarithms for firm i in year t, y is output, k is capital stock, n is labour, m is intermediate inputs, rd is the stock of R&D, ex_rd is the stock of external R&D (so as to capture spillovers from other innovating firms), t represents time (to represent technological change), and υ represents all other unobserved effects (including panel-data influences). The primary interest when estimating Equation (6.1) lies usually in the output elasticities with respect to the R&D stock (i.e. $\hat{\beta}_4$), as well as spillovers (i.e. $\hat{\beta}_5$). Deriving from Equation (6.1), its dynamic form has been preferred by some since the influence of individual firm fixed effects could be netted out by using such a procedure –

$$\Delta y_{it} = \lambda' + \beta_1' \Delta k_{it} + \beta_2' \Delta n_{it} + \beta_3' \Delta m_{it} + \beta_4' \Delta rd_{it} + \beta_5' \Delta ex\_rd_{it} + \Delta \upsilon_{it}$$

(6.2)

Nevertheless, Equations (6.1) and (6.2) are not equivalent as the former considers long-run effects whilst the latter only allows for short-run impacts[104]. Given its limitations, many empirical versions of (6.2) tend to substitute R&D spending per unit of sales (i.e. R&D intensity) for changes in the R&D stock –

$$\Delta y_{it} = \lambda' + \beta_1' \Delta k_{it} + \beta_2' \Delta n_{it} + \beta_3' \Delta m_{it} + \rho_1 (rd / y)_{it} + \rho_2 (ex\_rd / y)_{it} + \theta_{it}$$

(6.3)

where rd and ex_rd refer to (real) expenditures on R&D by the firm under consideration and the other firms (i.e. the spillover pool) respectively. The parameters of interest ρ_1 and ρ_2 now represent the rates of return on (or marginal productivity of) internal and external R&D rather than elasticities. The merit of such a setting lies in the fact that it allows the estimation of the growth rate of productivity using R&D intensity directly.

A number of studies have estimated various versions of Equation (6.1) using either cross-sectional or panel data at the firm/plant level, such as Griliches (1980), Schankerman (1981), Cuneo and Mairesse (1984), Griliches and Mairesse (1984, 1990), Griliches (1986, 1995), Jaffe (1986), Sassenou (1988), Hall and Mairesse (1995), Bartelsman *et al.* (1996), Mairesse and Hall (1996), Husso (1997), Cincera (1998), O'Mahoney and Vecchi (2000), Smith *et al.* (2004), Tsai and Wang (2004) and Aiello and Cardamone (2005). Covering a number of countries and time periods, these studies find that the overall mean value of the size of the output elasticity associated with the stock of R&D (i.e. $\hat{\beta}_4$) is around 0.12 (ranging from 0.01 to 0.29 across these studies). In addition, a recent study by Kafouros (2005) using firm-level UK data finds that the contribution of R&D to productivity over the 1989-2002 period was only 0.04 (i.e. a doubling of the R&D stock would have raised output by 4%). Moreover in the studies where external R&D stocks are also included to account for spillover effects, typically the productivity impact of the own firm's R&D stock is found to be much higher than

[104] To reconcile the two would require the estimation of, for example, an error-correction model that incorporates both short- and long-run impacts.

that of R&D stocks external to firms (e.g. a ratio of 4.5:1 in Aiello and Cardamone, 2005; and around 4:1 in Tsai and Wang, 2004).

Studies that have estimated the dynamic KPF (i.e. Equation, (6.2)) include Griliches (1980), Griliches and Mairesse (1983, 1984), Cuneo and Mairesse (1984), Mairesse and Cuneo (1985), Sassenou (1988), Hall and Mairesse (1995), Bartelsman *et al.* (1996), Mairesse and Hall (1996), Cincera (1998) and O'Mahoney and Vecchi (2000). The overall mean value of the size of the output elasticity associated with the stock of R&D (i.e. $\hat{\beta}_4'$) is found to be around 0.18 (ranging from 0.03 to 0.38). Thus in general, as expected, short-run estimates tend to be much higher than long-run estimates.

Meanwhile, various studies have also estimated rates of return in the setting of Equation (6.3), including Mansfield (1980), Link (1981, 1983), Griliches and Mairesse (1983, 1984, 1990), Odagiri (1983), Odagiri and Iwata (1986), Sassenou (1988), Goto and Suzuki (1989), Fecher (1990), Hall and Mairesse (1995), Bartelsman *et al.* (1996), Cincera (1998) and Wakelin (2001). Based on a number of time periods and countries, the overall mean value of the size of the rate of return associated with R&D spending (i.e. $\hat{\rho}_1$) is around 28.3 (ranging from 7 to 69 amongst these studies).

Lastly, in analogous models to those set out in Equations (6.1) and (6.2), the impact of spillovers has also been investigated in a number of firm-level studies, such as Jaffe (1989), Fecher (1990), Antonelli (1994), Raut (1995), Los and Verspagen (2000), Cincera (1998), Branstetter (2001). On balance, significant spillover effects have been documented in that the overall mean value of the size of the output elasticity with respect to the external R&D stock (i.e. $\hat{\beta}_5$ or $\hat{\beta}_5'$) is found to be around 0.45 (ranging from -0.31 to 1.46). This would imply that, on average, spillover effects associated with R&D are much larger on the firm than the direct impact of its own R&D stock. However, there is much more variation across the studies that investigate spillovers, suggesting that distinct data sources, differentiated methodologies and the inherent difficulties in accurately measuring spillover effects, all render the measurement of spillovers significantly more imprecise and open to bias.

6.1.2 The 'Two Faces of R&D' Approach

Another ever-expanding strand of the literature on the microeconomic impact of R&D activity on productivity has evolved from the literature on trade and growth, and the role that R&D and technology transfer plays in allowing lagging countries to 'catch up' with technological leaders (e.g. the US). Recent years have seen this emerging literature focus on the 'two faces of R&D' concept introduced by Cohen and Levinthal (1989), whereby R&D has a direct impact on TFP through innovative efforts together with an indirect channel whereby R&D provides the firm with the absorptive capacity to internalise the benefits gained from technology transfer.

Recent examples of the 'two faces of R&D' approach to measuring the impact of R&D on productivity can be found in Griffith *et al.* (2004), Cameron *et al.* (2005), Girma (2005) and Kneller (2005). These studies normally require estimates of TFP for firms located on the frontier of technology as well as firms in the country under consideration. Appealing to the literature on endogenous innovation and growth (e.g. Romer, 1990; Aghion and Howitt, 1992), this approach is based on the assumption that changes in TFP are determined directly by changes in the R&D knowledge stock (see Equation (6.2) above), while changes in the R&D stock can be proxied by (real) spending on R&D per unit of sales (see Equation (6.3) above). Thus, up to this point, the model is little different to those based on the KPF as discussed above.

Nevertheless, subsequently the determinants of TFP are supplemented by introducing technology transfer as a source of productivity growth; in other words, the larger the gap between TFP in the j-th frontier firm and TFP in firm i of interest, the greater the opportunity for 'catch-up' and thus for technology transfer. Put another way, the gap between productivity in firm j and firm i allows for a potential spillover in technology from the frontier firm j. Such technology transfer may take place autonomously, when there are no intervening variables included to link the technology gap (between TFP_j and TFP_i) to changes in TFP for firm i; or on the other hand, more realistically, technology transfer may require the recipient firm to possess a certain level of absorptive capacity (say proxied by R&D intensity, etc.) in order to be able to internalise the external technological transfer potentially available from the frontier firm(s). In a nutshell, the 'second-face' of R&D spurs faster adoption of new technologies. Thus, in its simplest form, the model can be specified as –

$$\Delta lnTFP_{it} = \rho_1\left(\frac{RD}{Y}\right)_{i,t-1} + \delta_1 ln\left(\frac{TFP_j}{TFP_i}\right)_{t-1} + \delta_2\left[\left(\frac{RD}{Y}\right)_{i,t-1} \times ln\left(\frac{TFP_j}{TFP_i}\right)_{t-1}\right]$$

(6.4)

where the first term on the RHS of the equation refers to the direct effect of R&D on TFP (via innovation); the second term measures autonomous technology transfer; and the last composite term (with associated impact δ_2) represents how technology transfer impacts on the firm's TFP depending on the level of absorptive capacity associated with the firm (see Griffith *et al.*, 2004, Equation 4).

The above model determining changes in TFP can be supplemented by including more than just R&D as a means of achieving innovations and technology transfer. For example, Cameron *et al.* (2005) include human capital and international trade as additional channels whereby innovation and technology transfers occur. Kneller (2005, Equation 6) employs a variable representing physical distance rather than international trade in his version of the model. Based on the linkage between FDI and technology gap, Girma (2005) interprets absorptive capacity – in a slightly different fashion – as being dependent on the size of the technology gap. It follows that one can replace R&D intensity (RD/Y) in Equation (6.4) by a vector Z that includes R&D, human capital and international trade, and rewrite (6.4) as –

$$\Delta lnTFP_{it} = \delta Z_{i,t-1} + \theta ln\left(\frac{TFP_j}{TFP_i}\right)_{t-1} + \mu\left[Z_{i,t-1} \times ln\left(\frac{TFP_j}{TFP_i}\right)_{t-1}\right]$$

(6.5)

In particular, based on industry-level panel data for 12 OECD countries during the 1974-1990 period, Griffith *et al.* (2004) have the findings that R&D positively impacts on TFP directly through generating innovations and indirectly through the technology transfer gap with the US (i.e. all three coefficients ρ_1, δ_1 and

δ_2 in Equation (6.4) are positive and significant). They also show that human capital stimulates innovation and absorptive capacity, but find no role for international trade. In contrast, in a similar setting but using data for 14 manufacturing industries in the US and UK for 1970-1992, Cameron *et al.* (2005), find no significant role for the 'second face' of R&D; in particular, their equivalent to the coefficient δ_2 in Equation (6.4) is not statistically significant. Instead they have found that international trade-based technology transfer is significant in determining UK productivity growth. In a similar vein, Kneller (2005)'s results imply no such significant impact of the 'second face' of R&D, but greater physical distance from the frontier firms does have the expected negative impact on technology transfer.

6.2 The Data and Some Descriptive Statistics

This last piece of empirical analysis utilises plant-level data for Northern Ireland to examine whether R&D capital stock impacts on productivity and if so, the nature of such a relationship. Business Enterprise Research and Development (henceforth *BERD*) data have been employed for this analysis[105], containing information on R&D spending in Northern Ireland for the 1993-2003 period, which make possible the calculation of an R&D capital stock for each plant. More specifically, nominal R&D spending is converted to real spending using the implied GDP deflator[106]. This may lead to some overestimation of the growth of the real knowledge stock, as the R&D inflation is likely to be relatively higher. Also, for multi-plant firms the R&D stock calculated from *BERD* can cover more than one plant located in Northern Ireland as *BERD* data are collected at the reporting-unit/establishment level. Thus the stock is allocated back to each plant based on its relative share of employment in the reporting unit (i.e. the 'share' of R&D stock of the plant is proportional to the share of its employment in the reporting unit). The number of multi-plant reporting units where this 'allocation' approach is applicable is rather small, and therefore no major impact is expected on the estimation results. For more details on the features of

[105] Note only *BERD* data for the region of Northern Ireland are employed to test the productivity effect of R&D, since when this analysis was being undertaken, comparable data were not yet available at the ONS to allow a comprehensive UK-wide study.

[106] This is the standard approach adopted in studies for the UK, as there is no separate deflator for R&D available.

the *BERD* database, refer to the data Appendix at the end of this chapter (pp. 256-259).

Both intra- and extra-mural spending is provided in the *BERD* data. Thus in-house R&D and R&D undertaken by firms are both included for the beneficiary concerned. Moreover, the depreciation rates used to calculate the R&D capital stock are adopted from Bloom *et al.* (2002). Four different assets are used with various depreciation rates (in parentheses), which are then added together to yield the total R&D stock, viz. intra-mural current spending (30% p.a.); plant & machinery R&D spending (12.6% p.a.); spending on buildings (3.6% p.a.); and extra-mural spending (assumed 30% p.a.). On average 90% of R&D spending in Northern Ireland was current spending, and therefore it is sufficient to use data from 1993 to calculate the 1998-2003 capital stock given the service life of such assets[107].

The annual *BERD* data can be linked to the *ARD*[108] at the level of the reporting unit/establishment. The dataset used in this empirical exercise has been constructed from merging the *BERD* and *ARD* data for the period 1998-2003 and the analysis is then undertaken at the *ARD* level of the plant (or local unit). Total capital expenditure data for each manufacturing plant (1998-2003) is disaggregated into its share spent on plant and machinery, converted to real prices, and then linked to historic plant-level real expenditure on plant and machinery for manufacturing covering 1970-1998. It is also worth noting that data for non-manufacturing in the *ARD* is only available from 1997 and therefore only manufacturing plants can be analysed using information on plant and machinery capital stock[109]. The data Appendix to this chapter (pp. 256-259) provides more information on merging *BERD* and *ARD* data and constructing capital stock in detail.

[107] Admittedly, much longer time series are needed for plant & machinery and buildings R&D investment in order to be able to accurately measure the stock of such assets, but since they only account for some 10% of spending, the R&D stock as measured here is assumed to be adequate.

[108] Refer to the data Appendix to Chapter 3 (pp.136-138) for a general description of the *ARD*, and the data Appendix to the current chapter for an introduction to the Northern Ireland *ARD* (pp. 256-259). Importantly, the financial data are weighted to obtain estimates that are representative of the population of UK establishments/plants.

[109] Note, during 1998-2003, the preponderance of the total R&D capital stock in Northern Ireland (i.e. 82%) was based in the manufacturing sector.

Table 6-1: Variable definitions and descriptive statistics

Variable	Definitions	Mean	Standard deviation
ln output	Real gross-output in plant *i* and time *t* (£m 2000 prices)	-1.274	1.769
ln capital	Plant & machinery capital stock for plant *i* in time *t* (source: Harris and Drinkwater, 2000, updated)	-4.602	3.264
ln employment	Current employment in plant *i* in year *t*	1.675	1.416
ln intermediate inputs	Real spending on intermediate inputs in plant *i* in year *t* (£m 2000 prices)	-1.875	1.880
ln age	Age of plant (*t* minus year opened +1) in years	1.258	0.934
ln R&D stock	1+ R&D stock in plant *i* and time *t* (£m 2001 prices)	-0.264	1.045
No R&D	Dummy coded 1 when plant *i* has zero R&D stock in year *t*	0.905	0.293
North/North West	Dummy coded 1 if plant located in Coleraine or Ballymena TTWA	0.115	0.319
South	Dummy coded 1 if plant located in Newry or Craigavon TTWA	0.189	0.392
West	Dummy coded 1 if plant located in Londonderry, Strabane, Enniskillen or Omagh TTWA	0.164	0.370
Mid-Ulster	Dummy coded 1 if plant located in Dungannon or Mid-Ulster TTWA	0.177	0.382
Old Commonwealth	Dummy coded 1 if plant *i* is owned at time *t* by either: Australian, New Zealand, South Africa, or Canada	0.001	0.032
Rep. of Ireland	Dummy coded 1 if plant *i* is Irish-owned at time *t*	0.012	0.109
SE Asia owned	Dummy coded 1 if plant *i* is SE Asian-owned at time *t*	0.002	0.040
US-owned	Dummy coded 1 if plant *i* is US-owned at time *t*	0.007	0.083
EU-owned	Dummy coded 1 if plant *i* is EU-owned at time *t*	0.006	0.075
GB-owned	Dummy coded 1 if plant *i* is GB-owned at time *t*	0.028	0.166
Single plant	Dummy coded 1 when plant *i* is a single plant in year *t*	0.896	0.305
SME	Single plant firms with less than 250 employees	0.887	0.317
ln (NI R&D)	R&D stock for 11 Northern Ireland industry groups in year *t*.[a]	2.543	0.988
ln (NI R&D) × R&D stock	R&D stock for 11 Northern Ireland industry groups in year *t* times R&D stock in plant *i* at time *t*	0.253	6.141
ln (UK R&D)	R&D stock for 21 UK industry groups in year *t*.[b]	5.818	1.184
ln (UK R&D) × R&D stock	R&D stock for 21 UK industry groups in year *t* times R&D stock in plant *i* at time *t*	0.479	10.394

Notes: year dummies included in the model to take account of technical change and other temporal shocks.
[a] Obtained by summing across plants in each of the 11 industry groups modelled (see results)
[b] Obtained using real R&D spending in UK for 1993-2003 (separately for intramural and two types of capital assets), and using same perpetual inventory approach as used to obtain NI plant-level data, in each of the 21 industry groups available in the Business Monitor MA14 published tables.

Table 6-1 provides definitions of variables in the merged *BERD-ARD* dataset, which are included in subsequent empirical analysis, as well as some descriptive statistics. Some descriptive statistics are presented with respect to some characteristics of the R&D spending in Northern Ireland. Table 6-2 shows the breakdown of business R&D spending by industry: how intramural spending was distributed in 2001 (in terms of both value and percentages)[110]. In particular,

[110] Note SIC 2003 in the Northern Ireland *BERD* was not complete at the time of this analysis, hence the 2001 SIC codes were used.

over 43% of R&D spending in Northern Ireland was attributed to the *Radio, Television and Communications equipment* sector. This sector is not particularly large in terms of the regional economy (it accounted for some 4.8% of total Northern Ireland manufacturing GVA in 2001), and Table 6-3 shows that while it has a relatively high R&D intensity (R&D spending equated to 7.7% of sales in 2001), this intensity is not significantly different to that of the UK for this industry.

Table 6-2: Business R&D spending by industry sector, Northern Ireland vs. UK, 2001 (£m)

Industrial sector	NI	*%*	UK	*%*
Food, drink & tobacco	8.7	*5.8*	314	*2.5*
Textiles, clothing & leather	1.6	*1.1*	17	*0.1*
Pulp, paper, printing & wood products	0.3	*0.2*	34	*0.3*
Chemicals, man-made fibres	9.3	*6.2*	522	*4.2*
Pharmaceuticals, electrical machinery & aerospace	10.1	*6.7*	4,751	*38.5*
Rubber & plastics	1.3	*0.9*	45	*0.4*
Other non-metallic mineral products	0.5	*0.3*	41	*0.3*
Fabricated metal products	2.5	*1.7*	64	*0.5*
Machinery & equipment	22.5	*15.0*	843	*6.8*
Radio, television & communication equipment	65.2	*43.5*	1,044	*8.5*
Precision instruments	2.8	*1.9*	488	*4.0*
Motor vehicles & parts	2.0	*1.3*	989	*8.0*
Wholesale & retail trade	0.5	*0.3*	55	*0.4*
Miscellaneous Business activities	2.2	*1.5*	242	*2.0*
Computer & related activities	7.5	*5.0*	725	*5.9*
R&D services	3.6	*2.4*	495	*4.0*
Other sectors	9.5	*6.2*	1,667	*13.5*
Total	150.0	*100.0*	12,336	*100.0*

Source: NI *BERD*; Business Monitor MA14 (2003); Forfás (2005).

Table 6-2 and Table 6-3 imply that the most important sector for R&D in the UK (both in terms of spending and intensity) is *pharmaceuticals*, *electrical machinery and aerospace*[111]. In Northern Ireland, spending is much lower, and more importantly R&D intensity is some 15 times smaller than in the UK[112].

In summary, Northern Ireland seems to have a significantly different pattern of R&D spending across industrial sectors vis-à-vis the UK, which in part reflects its different industrial specialisations, its narrower industrial base, and generally its lower R&D intensity in those industries that are most important to the local economy.

[111] These industries are grouped together to ensure confidentiality with regard to the Northern Ireland data.

[112] In terms of Northern Ireland's manufacturing GVA, this sector accounted for nearly 13% in 2001.

Table 6-3: R&D per unit of sales, 2001, by manufacturing sector, Northern Ireland and UK

Manufacturing sector	NI	UK
Food, drink & tobacco	0.2	0.6
Textiles, clothing & leather	0.7	0.2
Pulp, paper, printing & wood products	0.4	0.1
Chemicals, man-made fibres	2.9	2.0
Pharmaceuticals, electrical machinery & aerospace	1.1	15.1
Rubber & plastics	1.1	0.3
Other non-metallic mineral products	1.6	0.4
Fabricated metal products	2.9	0.3
Machinery & equipment	8.6	3.2
Radio, television & communication equipment	7.7	7.1
Precision instruments	17.6	5.4
Motor vehicles & parts	0.9	8.4
Other manufacturing	3.2	2.1
Total	1.5	3.2

Source: NI *BERD*; Business Monitor MA14 (2003); Forfás (2005).

6.3 The Empirical Model

With respect to the empirical R&D-productivity relationship, following the discussion above on the estimation strategies adopted in the literature, this section considers the impact of R&D spending on output from the supply-side, by estimating a ‘knowledge production function’ (KPF), as developed by Griliches (1980), using Northern Ireland plant-level data for different industries –

$$y_{it} = \alpha + \beta_1 k_{it} + \beta_2 n_{it} + \beta_3 m_{it} + \beta_4 rd_{it} + \lambda t + \upsilon_{it} \tag{6.6}$$

where lower case variables denote (natural) logarithms, y is output, k is capital stock, n is labour, m is intermediate inputs, rd is the stock of R&D, t represents time (technical progress), and υ represents all other impacts (including panel data influences). This model can be extended to capture R&D spillovers[113] as well as other factors that impact on output (and thus TFP). The primary interest when estimating Equation (6.6) will be the size of the output elasticity associated with the stock of R&D (i.e. $\hat{\beta}_4$).

[113] The usual approach to studying R&D spillovers is to include the total R&D stock for the industry in which the plant operates, for backward- and forward-linked industries, and/or for all firms in the locality in which the plant operates.

Consequently, Equation (6.6) is used with plant-level data for Northern Ireland covering 1998-2003. Note, the R&D stock for each plant is logged in the model, and therefore this variable has to be entered as (1 + R&D stock)[114]. To account for any bias from converting the R&D stock in this way, a separate dummy variable is included (denoted 'No R&D') which takes on a value of 1 if the plant's R&D stock equals zero. Separate equations are estimated for each industry and the KPF is enhanced to include other aspects of TFP (i.e. impacts on output not directly associated with factor inputs), including the following – the age of the plant; the country of ownership of the plant (including GB-owned plants); the sub-region of Northern Ireland where the plant is located; whether the plant is a single-plant enterprise; and lastly whether it is an SME.

In order to incorporate the spillovers effect of R&D, two measures have been experimented – the first measure (designated NI R&D and designed to pick up local intra-industry spillovers) comprises the sum of R&D stocks for Northern Ireland plants in the same 2-digit industry group; and the other measure (labelled UK R&D and designed to cover UK-wide intra-industry spillovers) is composed of the UK R&D stock in the same 2-digit industry. The definition of industry group differs for these two measures due to the differences in industrial structure between the Province and the UK (e.g. sectors undertaking R&D), and data availability (e.g. the UK data is based on the industry sub-groups used in the published Business Monitor MA14 reports for the UK).

Neither of these measures is ideal, and other approaches have also been attempted such as calculating R&D stocks for Northern Ireland for each 2-digit sector sub-divided into 5 major sub-regions (based on travel-to-work areas). The latter measure recognises more explicitly the likely decay of external technological information with distance, but it proves no more significant in the results that follow and is therefore dropped in favour of the Province-wide measure.

In addition to all these measures, rather than spillovers accruing to all plants, other methods have also been experimented by entering the relevant spillover measures multiplied by a plant's R&D stock (e.g. *ln* (NI R&D) $\times$ R&D stock can be

[114] Thus plants with no R&D stock returns a value of zero using the variable *ln* (1+R&D stock), in doing so the unwanted loss of data could be avoided.

used instead of the *ln* (NI R&D) measure). This potentially allows the absorption of external R&D to be proportionate to the amount of accumulated R&D in the plant, with the expectation that plants that have larger own R&D stock have a greater ability to internalise any spillovers from external R&D that takes place in the same industry and/or location.

All the variables used to estimate Equation (6.6) are set out in Table 6-1. The DPD system GMM panel estimator is used with the merged plant-level *BERD-ARD* data. The plant & machinery capital stock, employment, (real) intermediary inputs and R&D are treated as potentially endogenous and are instrumented using lagged values – in both levels and first differences – of each variable, whilst all other variables in the model are predetermined and form their own instruments.

6.4 Estimation Results

The full short-run results for all 11 industry groups are presented in Table 6-5 (in the Appendix, pp.259-263). In terms of model diagnostics, the results show that this model passes the Sargan (χ^2) test of over-identifying restrictions, an indication of appropriateness of the instruments; and there is no evidence of second-order autocorrelation. In addition, importantly, the test of the slope coefficients for omitted variables being jointly equal to zero cannot be rejected, as statistically insignificant regressors have been dropped from each model.

These short-run results in Table 6-5 show that when there are changes in the RHS variables in the model, gross output adjusts relatively fast over time to a new steady-state. Output adjustment in the *rubber & plastic* sector takes about 1.15 years, while adjustment in the *electrical & precision* sector takes just under 2 years[115].

More importantly, the long-run results are presented in Table 6-4 to demonstrate the relationship in the steady-state/equilibrium. The key variables in this analysis are the impact of the R&D stock and R&D spillovers on output.

[115] These figures are obtained by using the parameter estimate for *ln* gross output$_{t-1}$. If this is given the value λ, then the speed of adjustment is $1/(1-\lambda)$.

The R&D stock have a positive impact on output in nearly every industry except the *textiles* sector: a 10% increase in the R&D stock results in an increase in the output ranging from 0.3% in *clothing* through to a 1.7% increase in the *food & drink* sector. In addition, plants with a zero R&D stock experience significant one-off negative productivity effects, ranging from −7% in chemicals to −62% in *food & drink*[116] (although there is no significant effect in the *textiles*, *clothing*, *non-metallic minerals* and *fabricated metals* sectors).

[116] Since the dependent variable is in log-form, the impact of a dichotomous variable is obtained as $e^{\hat{\beta}} - 1$.

Table 6-4: Long-run estimates of Equation (6.6) for Northern Ireland Industry Groups, 1998-2003

Dependent variable: *ln* real gross output	Food & drink (15)		Textiles (17)		Clothing (18)		Chemicals (24)		Rubber & plastics (25)		Non-metallic minerals (26)	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln capital_t	0.119	2.76	0.134	2.35	0.180	3.59	0.209	2.50	0.131	2.76	0.091	1.88
ln employment_t	0.135	2.09	0.279	6.51	0.433	7.94	0.433	13.59	0.268	2.16	0.340	2.71
ln intermediary inputs_t	0.947	64.33	0.712	18.26	0.712	12.18	0.591	18.83	0.668	33.27	0.782	7.37
ln Age_t	0.097	2.28	-0.106	-3.27	–	–	–	–	–	–	–	–
ln $\text{R\&D}_t$	0.166	2.78	–	–	0.026	2.27	0.077	1.65	0.031	2.13	0.041	2.16
No R&D	-0.960	-3.07	–	–	–	–	-0.073	-3.01	-0.204	-2.25	–	–
North/North West	–	–	0.111	3.14	–	–	0.160	1.19	–	–	–	–
South	–	–	–	–	–	–	–	–	–	–	–	–
West	–	–	–	–	–	–	–	–	–	–	–	–
Mid-Ulster	–	–	–	–	–	–	–	–	–	–	–	–
US-owned	–	–	0.530	2.26	–	–	–	–	-0.261	-2.86	–	–
GB-owned	–	–	–	–	-0.213	-1.42	–	–	–	–	–	–
Single plant	0.201	3.80	–	–	0.349	2.01	–	–	–	–	–	–
SME	-0.121	-2.42	–	–	–	–	–	–	–	–	–	–
ln $(\text{NI R\&D})_t$	–	–	–	–	–	–	-0.114	-4.81	–	–	–	–
ln $(\text{UK R\&D})_t \times \text{R\&D}_t$	–	–	–	–	–	–	–	–	–	–	–	–
ln $(\text{UK R\&D})_t$	–	–	–	–	–	–	–	–	–	–	–	–

See Table 6-5 for details.

Table 6-4 (cont.)

	Fabricated metals (28)		Machinery & equipment (29)		Electrical & precision (30-33)		Motor vehicles & other transport (34-35)		Other manufacturing	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln $capital_t$	0.187	3.15	0.167	12.00	0.316	5.19	0.382	9.13	0.165	2.72
ln $employment_t$	0.571	9.97	0.396	21.01	0.421	8.13	0.285	5.81	0.245	10.60
ln intermediary $inputs_t$	0.558	43.54	0.452	17.00	0.262	2.78	0.285	5.47	0.713	42.99
ln Age_t	–	–	-0.185	-7.47	–	–	–	–	–	–
ln $R\&D_t$	0.028	3.85	0.029	1.72	0.131	2.53	0.047	5.84	0.054	1.62
No R&D	–	–	-0.035	-3.16	-0.145	-2.63	-0.132	-8.11	-0.232	-1.72
North/North West	–	–	–	–	–	–	–	–	-0.081	-4.28
South	–	–	–	–	–	–	–	–	-0.061	-3.04
West	–	–	–	–	–	–	–	–	-0.053	-2.74
Mid-Ulster	–	–	–	–	–	–	–	–	-0.058	-3.24
US-owned	–	–	0.235	1.89	–	–	–	–	–	–
GB-owned	–	–	0.190	2.09	–	–	–	–	–	–
Single plant	–	–	–	–	–	–	–	–	–	–
SME	–	–	–	–	–	–	–	–	-0.154	-4.64
ln $(\text{NI R\&D})_t$	–	–	–	–	–	–	–	–	–	–
ln $(\text{UK R\&D})_t \times R\&D_t$	–	–	0.002	2.16	–	–	–	–	0.012	4.71
ln $(\text{UK R\&D})_t$	–	–	–	–	–	–	0.085	2.84	–	–

Spillover effects are largely absent. In the *chemicals sector* a 10% increase in the R&D stock for that sector in Northern Ireland reduces plant-level productivity by some 1.1%, suggesting negative spillover effects and a tendency for Northern Ireland plants in this sector to 'free-ride' on the back of R&D undertaken by other firms. There is a very small (but significant) positive spillover from UK R&D in the *machinery & equipment* sector, but this benefits only those plants in the Province that have matching levels of absorptive capacity. In *motor vehicles & other transport*, a 10% increase in the UK R&D stock results in a 0.9% increase in productivity through spillovers, and in *other manufacturing* plants with sufficient level of absorptive capacity also experience a 0.1% increase in productivity for a 10% increase in the UK R&D stock relevant to this sector.

With regard to the impact of other variables in Equation (6.6) , returns-to-scale (obtained by summing the output elasticities across factor inputs) are present in all sectors; 'age' effects are not very important overall (although older plants in the *textiles and machinery & equipment* sectors experience lower productivity); location effects are mostly absent, with location in the North/North West imparting some positive effects for the t*extiles and chemicals* sectors, whilst *other manufacturing* having lower productivity outside of the benchmark sub-region of Belfast; being US-owned has a significant positive productivity effect in the *textiles and machinery & equipment* sectors (resulting in *cet. par*. between 26-70% higher output levels) but a negative impact in *rubber & plastics* (23% lower productivity); GB-owned plants do worse in the *clothing* sector but better in m*achinery & equipment*; single plant enterprises have higher productivity in *food & drink* and *clothing*; and SMEs have lower productivity in *food & drink* and *other manufacturing*.

6.5 Conclusions

This chapter attempts to provide an initial analysis of the impact of R&D spending (as well as spillovers from R&D) on productivity, by estimating the 'knowledge production function' separately for different manufacturing industries, based on plant-level data from Northern Ireland for the 1998-2003 period. Overall, the steady-state results suggest that, in the long run, R&D stock has a positive impact on output in all industries (except the *textiles* sector). In particular, the impact of a 10% increase in the R&D stock ranges from a 0.3% increase in output in *clothing* through to a 1.7% increase in the *food & drink* sector. In addition, plants with a zero R&D stock experience significant one-off negative productivity effects, ranging from −7% in c*hemicals* to −62% in *food & drink* (although there is no significant effect in the *textiles*, *clothing*, *non-metallic minerals* and *fabricated metals* sectors).

In addition, as set out at the beginning of this chapter, it also attempts to estimate the impact of spillovers from R&D undertaken by other businesses. Nevertheless, those spillover effects are found to be largely absent for Northern Ireland manufacturing. Moreover, in terms of the parameter estimates included in the empirical model, results obtained indicate universal returns-to-scale in all sectors. Despite some disadvantage of older plants in the *textiles and machinery & equipment* sectors, on balance, age of the plant is not very important in explaining productivity differences. Regional effects are also mostly absent on the whole, with some positive effect for the t*extiles and chemicals* sectors located in the North/North West; and some negative productivity effect associated with *other manufacturing* sector outside of Belfast. Noticeably, ownership does matter: being US-owned is found to exert a significant positive productivity effect in the *textiles and machinery & equipment* sectors but a negative impact in *rubber & plastics*; GB-owned plants do worse in the *clothing* sector but better in m*achinery & equipment*. Lastly, single-plant enterprises have higher productivity in *food & drink* and *clothing* sectors; whilst SMEs having lower productivity in *food & drink* and *other manufacturing*.

Appendix

Data Construction − Merging BERD and ARD datasets

- **The Annual Respondents Database for Northern Ireland (*NI ARD*)**

The Annual Respondents Database (*ARD*) for Northern Ireland (1998-2003) are provided by the Department of Enterprise, Trade and Investment (DETI) in Northern Ireland at levels of plant/local unit (LU) and establishment/reporting unit (RU). LU data are used for this analysis on the impact of R&D on productivity, but the RU datasets provide information that is sometimes missing from the LU datasets (e.g. on postcodes, IDBR enterprise reference numbers and foreign ownership markers). Such RU data are then ‘spread back’ to local units based on the IDBR reporting unit codes contained in both LU and RU datasets.

The 1998-2003 LU files are merged and ‘cleaned’, and missing data repaired with regard to postcodes, ownership and enterprise level codes (which are necessary to calculate whether the plant is a single-plant enterprise or belongs to other enterprises). Postcodes are needed to link plants to travel-to-work areas (TTWA) and sub-regional areas; ownership and enterprise level data mean that plants can be identified in terms of whether they are single plants, GB-owned or foreign owned.

Total capital expenditure data for each manufacturing plant (1998-2003) are broken-down into the share spent on plant and machinery[117], converted to real prices, and then linked to historic plant-level real expenditure on plant and machinery for manufacturing covering 1970-1998. Note, data for non-manufacturing in the *ARD* are only available from 1998 and therefore only manufacturing plants can be analysed for this study using plant and machinery capital stock information. The 1970-1998 data are obtained from Harris *et al.* (2002), and the full 1970-2003 information (together with pre-1970 benchmark data) is used to calculate the plant and machinery capital stock for each plant based on the methods set out in Harris and Drinkwater (2000).

- **The Business Enterprise Research and Development Database (*BERD*)**

The *BERD* is an annual survey designed to measure Research and Development (R&D) expenditure and employment in all industries in the UK, including sources of funding and types of R&D. The *BERD* data are collected by the ONS to be used by the Sources Directorate to produce R&D statistics; and similar to the *ARD*, these data are also used to generate the National Accounts. The sample of the *BERD* is drawn on a number of sources such as the Annual Business Inquiry (where there is a marker to indicate whether or not a firm undertakes R&D); the

[117] 1999 and 2000 3-digit industry data for Northern Ireland data are available and thus used to convert 1998-2003 plant-level capital spending into an amount spent on plant & machinery and an amount spent on new building, land and vehicles.

DTI and Scottish Government (who keep records of R&D information on companies); and finally the press.

The concept of R&D used in *BERD* is defined according to the *Frascati* manual – the "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including the knowledge of man, culture and society and the use of this stock of knowledge to devise new applications" – which allows comparative analysis of R&D on an international basis.

Establishments in the sample are requested to fill in either a 'long form' (for larger reporting units) or 'short form' (for smaller businesses). The 'long form' gathers information on both intramural (in-house) and extramural R&D, with information broken down by product group and purpose (i.e. civil or defence). In terms of the intramural R&D, it covers current R&D expenditure on the following three areas: basic research, applied research and experimental research. As for the extramural R&D, which refers to the R&D commissioned outside the company, this includes R&D commissioned within the UK (e.g. through universities, government establishments, private/public labs, etc.); R&D purchased by businesses outside the UK but using funding from central government; and all other R&D expenditure outwith the UK.

On the other side, the 'short form' collects information only by asking three questions: aggregate figures for intramural R&D, purchase of extramural R&D and average (FTE) employment on R&D. Therefore, for the 'short form', figures have to be imputed from other sources or estimated rather than returned by respondents answering the *BERD* survey, in order to provide information on all variables covered by the 'long form'.

Business Enterprise Research and Development (*BERD*) data for Northern Ireland are obtained from the DETI, for the years of 1993, 1996, 1999 and 2001-2003, covering information on R&D spending at RU level. Data for the missing years are requested from the ONS so that it could be used to provide a full 1993-2003 panel dataset on business R&D spending in Northern Ireland. With 1993-2003 *BERD* data at the RU level, it is possible to calculate a R&D capital stock for each plant. To ensure a proper match at LU level that could be linked into the 1998-2003 *ARD* for Northern Ireland detailed above, this is done in two stages: firstly, the 1993-1997 *BERD* data at RU level are used to calculate the 1997 benchmark R&D capital stock. This is then ‘spread’ to LU’s operating in 1998 in the *ARD* based on their employment shares in each RU. This benchmark stock is then allowed to depreciate with no further investment for 1998-2003. *BERD* data on R&D spending at RU for 1998-2003 are also ‘spread’ to LU’s in the 1998-2003 *ARD* (using LU employment shares in each RU), and a second R&D capital stock is calculated at plant level for 1998-2003 which is then added to the 1997 benchmark data for LU’s covering 1998-2003. This results in the total R&D capital stock for each plant in operation during 1998-2003.

Full Estimation Results of the R&D-Productivity Modelling

Table 6-5: Estimates of Equation (6.6) for Northern Ireland Industry Groups, 1998-2003

Dependent variable *ln* real gross output	Food & drink (15)*		Textiles (17)		Clothing (18)	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln gross output$_{t-1}$	0.234	3.92	0.153	2.12	0.163	2.63
ln capital$_t$	0.091	2.97	0.114	2.06	0.151	3.00
ln capital$_{t-1}$	–	–	–	–	–	–
ln employment$_t$	0.159	2.52	0.333	10.20	0.657	4.85
ln employment$_{t-1}$	-0.056	-2.39	-0.097	-2.83	-0.294	-1.77
ln intermediary inputs$_t$	0.880	60.50	0.743	23.30	0.850	10.10
ln intermediary inputs$_{t-1}$	-0.155	-3.07	-0.139	-2.39	-0.254	-3.78
ln Age$_t$	0.074	1.43	-0.090	-3.14	–	–
ln R&D$_t$	0.127	2.70	–	–	0.022	2.92
No R&D	-0.735	-1.88	–	–	–	–
North/North West	–	–	0.094	2.92	–	–
South	–	–	–	–	–	–
West	–	–	–	–	–	–
Mid-Ulster	–	–	–	–	–	–
Old Commonwealth	–	–	–	–	–	–
US-owned	–	–	0.449	2.14	–	–
GB-owned	–	–	–	–	-0.178	-1.44
Single plant	0.154	2.32	–	–	0.292	2.05
SME	-0.093	-1.48	–	–	–	–
ln (NI R&D)$_t$	–	–	–	–	–	–
ln (UK R&D)$_t$ × R&D$_t$	–	–	–	–	–	–
ln (UK R&D)$_t$	–	–	–	–	–	–
Restricted (β= 0) χ^2 [p-value]	8.9	[0.542]	5.4	[0.979]	7.8	[0.648]
Sargan test χ^2 [p-value]	53.5	[0.416]	48.2	[0.624]	33.6	[0.978]
AR(1) [p-value]	-2.12	[0.034]	-1.57	[0.116]	0.39	[0.696]
AR(2) [p-value]	0.95	[0.331]	-0.18	[0.854]	0.04	[0.971]
R^2	0.96		0.98		0.95	
No. of observations	1,723		744		475	
No. of units	548		239		171	
instruments	Δt–1, t–2		Δt–1, t–2		Δt–1, t–2	

Notes: * SIC 2-digit codes are included in parentheses. All models are estimated using system GMM estimator, unless otherwise noted (GLS).Year dummies included in all regressions to control for time effects.

Table 6-5 (cont)

Dependent variable *ln* real gross output	Chemicals (24)		Rubber & plastics (25)		Non-metallic minerals (26)	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln gross output$_{t-1}$	0.237	8.73	0.131	2.12	0.422	6.33
ln capital$_t$	0.160	2.88	0.114	2.85	0.053	2.23
ln capital$_{t-1}$	–	–	–	–	–	–
ln employment$_t$	0.331	20.50	0.233	2.23	0.542	2.85
ln employment$_{t-1}$	–	–	–	–	-0.345	-2.65
ln intermediary inputs$_t$	0.609	28.90	0.896	34.30	0.756	8.84
ln intermediary inputs$_{t-1}$	-0.158	-4.05	-0.316	-1.64	-0.304	-4.44
ln Age$_t$	–	–	–	–	–	–
ln R&D$_t$	0.058	1.69	0.033	2.69	0.024	2.29
No R&D	-0.056	-3.22	-0.177	-2.32	–	–
North/North West	0.122	1.24	–	–	–	–
South	–	–	–	–	–	–
West	–	–	–	–	–	–
Mid-Ulster	–	–	–	–	–	–
Old Commonwealth	–	–	–	–	–	–
US-owned	–	–	-0.226	-2.95	–	–
GB-owned	–	–	–	–	–	–
Single plant	–	–	–	–	–	–
SME	–	–	–	–	–	–
ln (NI R&D)$_t$	-0.087	-5.48	–	–	–	–
ln (UK R&D)$_t$ × R&D$_t$	–	–	–	–	–	–
ln (UK R&D)$_t$	–	–	–	–	–	–
Restricted (β= 0) χ^2 [p-value]	5.7	[0.956]	3.9	[0.958]	3.5	[0.995]
Sargan test χ^2 [p-value]	–		25.6	[1.000]	61.2	[0.178]
AR(1) [p-value]	0.49	[0.623]	-2.02	[0.044]	-1.64	[0.100]
AR(2) [p-value]	-1.16	[0.248]	1.47	[0.142]	1.48	[0.140]
R^2	0.94		0.95		0.82	
No. of observations	312		1,072		1,684	
No. of units	81		334		500	
instruments	GLS		Δt−1, t−2		Δt−1, t−2	

Table 6-5 (cont)

Dependent variable *ln* real gross output	Fabricated metals (28)		Machinery & equipment (29)		Electrical & precision (30-33)	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln gross output$_{t-1}$	0.385	8.39	0.215	6.90	0.478	5.33
ln capital$_t$	0.115	2.67	0.131	13.00	0.203	8.61
ln capital$_{t-1}$	–	–	–	–	-0.038	-5.37
ln employment$_t$	0.351	8.45	0.310	22.20	0.164	13.10
ln employment$_{t-1}$	-0.345	-2.65	–	–	0.055	6.10
ln intermediary inputs$_t$	0.596	36.90	0.429	13.60	0.208	14.20
ln intermediary inputs$_{t-1}$	-0.253	-11.60	-0.074	-3.82	-0.071	-3.39
ln Age$_t$	–	–	-0.146	-7.30	–	–
ln R&D$_t$	0.017	3.26	0.023	1.75	0.068	2.62
No R&D	–	–	-0.027	-3.22	-0.076	-3.28
North/North West	–	–	–	–	–	–
South	–	–	–	–	–	–
West	–	–	–	–	–	–
Mid-Ulster	–	–	–	–	–	–
Old Commonwealth	–	–	–	–	–	–
US-owned	–	–	0.184	1.78	–	–
GB-owned	–	–	0.149	2.06	–	–
Single plant	–	–	–	–	–	–
SME	–	–	–	–	–	–
ln (NI R&D)$_t$	–	–	–	–	–	–
ln (UK R&D)$_t$ × R&D$_t$	–	–	0.002	2.19	–	–
ln (UK R&D)$_t$	–	–	–	–	–	–
Restricted (β= 0) χ^2 [p-value]	16.6	[0.278]	5.5	[0.939]	17.6	[0.226]
Sargan test χ^2 [p-value]	60.2	[0.292]	na		na	
AR(1) [p-value]	0.84	[0.398]	1.32	[0.188]	-1.45	[0.146]
AR(2) [p-value]	0.99	[0.324]	1.72	[0.085]	0.86	[0.389]
R^2	0.99		0.93		0.82	
No. of observations	2,972		1,405		839	
No. of units	986		376		221	
instruments	Δt−1, t−2		GLS		GLS	

Table 6-5 (cont)

Dependent variable *ln* real gross output	Motor vehicles & other transport (34-35)		Other manufacturing	
	$\hat{\beta}$	*t*-value	$\hat{\beta}$	*t*-value
ln gross output$_{t-1}$	0.346	5.04	0.238	4.65
ln capital$_t$	0.340	8.15	0.126	2.97
ln capital$_{t-1}$	-0.090	-5.51	-0.013	-2.09
ln employment$_t$	0.111	7.94	0.120	3.22
ln employment$_{t-1}$	0.076	3.40	0.067	2.23
ln intermediary inputs$_t$	0.231	15.40	0.740	40.40
ln intermediary inputs$_{t-1}$	-0.044	-1.06	-0.196	-5.49
ln Age$_t$	–	–	–	–
ln R&D$_t$	0.031	4.18	0.041	1.63
No R&D	-0.087	-6.73	-0.177	-1.72
North/North West	–	–	-0.062	-4.17
South	–	–	-0.047	-3.04
West	–	–	-0.041	-2.75
Mid-Ulster	–	–	-0.045	-3.16
Old Commonwealth	–	–	–	–
US-owned	–	–	–	–
GB-owned	–	–	–	–
Single plant	–	–	–	–
SME	–	–	-0.117	-4.11
ln (NI R&D)$_t$	–	–	–	–
ln (UK R&D)$_t$ × R&D$_t$	–	–	0.009	4.34
ln (UK R&D)$_t$	0.055	2.75	–	–
Restricted (β= 0) χ^2 [p-value]	18.0	[0.387]	6.2	[0.517]
Sargan test χ^2 [p-value]	na		49.6	[0.568]
AR(1) [p-value]	2.11	[0.034]	-5.06	[0.000]
AR(2) [p-value]	1.56	[0.118]	0.60	[0.547]
R^2	0.93		0.96	
No. of observations	552		6,459	
No. of units	148		2,129	
instruments	GLS		Δt–1, t–2	

Chapter 7: Final Conclusions and Policy Implications

This thesis attempts to employ a resource-based approach to advancing the understanding of various aspects of the firm's behaviour (with exporting and innovation being two main resource-building and knowledge-generating activities under investigation), their inter-relationships as well as impacts on the firm's performance. Chapter 1 starts with an introduction to the resource-based theories and a discussion on their applications in providing an explanation for the sustained differences amid firms (in the context of micro exporting and innovating activities) by identifying and analysing the heterogeneity in firm-specific resources.

Throughout the chapter, emphasis has been placed on heterogeneous resources and capabilities as being the fundamental productive entities of production and exchange in the economy, which significantly distinguishes the RBV from mainstream IO framework that sets its focus on goods and services. In contrast to goods and services in the neoclassical sense, such resources do not exist outside the firm, but are only contained within; they can be developed by firms internally as well as traded/acquired from outside. Indeed, in providing an explanation for the role of resources and capacities in innovation activity, it has been argued that those innovative resources can be generated and/or upgraded both internally through the processes that improve the firm's internal capabilities as well as externally through its acquiring and appropriating knowledge or R&D outwith itself.

When addressing the linkage between innovation and internal capacities of the firm, the notion of absorptive capacity has been stressed throughout the discussion, which is argued to be of paramount importance to understanding the implication of RBV for the generation and sustainment of competitive advantage crucial to the firm's innovative activity. Absorptive capacity is often regarded as a strategically valuable capacity due to its firm-specific, path-dependent and evolutionary nature in appropriating external knowledge for the generation of competitive advantage within firms. The importance of absorptive capacity to firm-level innovating behaviour is best seen in providing an analytical link between the firm's in-house innovative resources and the external stock of knowledge in enhancing its resource base and generating knowledge.

The remaining part of Chapter 1 deals with the firm's export orientation emphasising the RBV component in understanding the process of business internationalisation. It considers various models that have featured in the literature (of business, management and economics) that attempts to explain why and how certain firms internationalise and others stay in the domestic market. No matter which model is considered, be the traditional, incremental model of internationalisation, the 'born-global' model of early internationalisation, the transaction-cost model, the monopolistic-advantage model or more recent economics models (emphasising firm heterogeneity and sunk costs), a strong overlapping feature lies in the important role played by firm-specific assets (e.g. complementary resources and absorptive capacity) and knowledge accumulation.

The more recent economic models of internationalisation in particular, have focused on the importance of sunk costs and heterogeneity across firms (i.e. mostly embodied in distinct productivity levels). To overcome entry costs, firms need an adequate knowledge-base and complementary assets/resources (especially R&D and human capital assets that lead to greater absorptive capacity); and of course, productivity differences rely on firms having differing knowledge and resource-bases associated with discrepancies in innovation and other knowledge-generating activities. Needless to say, in addition to the role of knowledge and capacities, the literature has identified other factors that determine internationalisation, such as industrial sector (e.g. whether high-tech or not), firm size, networks/agglomerations, the international experience of the management, even serendipity, etc. Nevertheless, a recurring emphasis throughout the literature is the importance of (tacit) knowledge generation and acquisition, both within the firm and from its external environment.

All in all, various theories of internationalisation in the literature are underpinned by the overlapping assumption that international activities are determined by the resources and capabilities possessed by firms, which allow them to overcome the initial (sunk) costs of competing in international markets. It is worth noting that there is a direct link to the notion of absorptive capacity and the role of innovative activity in the internationalisation process, which however are areas generally not considered in any detail especially in the mainstream economics literature. That is, despite this leading role of knowledge accumulation and absorptive capacity, there is still a dearth of evidence on how organisations learn and exactly how these capacities (especially various dimensions of absorptive capacity) can be measured so as to quantify their relative importance. It follows that Chapter 1 has identified that there is still much research that needs to be undertaken to add to the evidence base of the extant literature and thus 'flesh-out' some of the RBV concepts and arguments put forward in this chapter.

Chapter 2 reviews the literature surrounding the firm's exporting and innovation activities, in an attempt to identify the factors that have been documented to have a deciding impact upon whether the firm participates in these activities in the first instance; and then conditional on participation, the intensity of such knowledge-creating/resource-building activities (per unit of total sales). In addition to some conventional firm-specific characteristics that might exert an influence (such as size, productivity, capital intensity, etc.), a number of other factors have been suggested in the literature to determine these firm-level activities (i.e. propensity of participation and/or intensity), for instance, in the case of exporting orientation, absorptive capacity, R&D, industrial/market concentration, spatial agglomeration, export spillovers, international outsourcing, etc.; and in the case of innovation behaviour, determinants including absorptive capacity, ownership, technological opportunities, R&D spillovers and external localisation, industrial effect, exports, government assistance as well as some factors serving as barriers to innovation.

Having identified an inter-linkage between export and innovation behaviour at the firm level, Chapter 2 finishes with a survey of both theoretical and empirical evidence supporting such a causal relationship, and subsequently the direction of the causation. From a RBV perspective, the innovation-led exports can be understood by studying the facilitating role played by technological resources in the firm's internationalisation process, which confer cost/product differentiation advantages that are vital in helping the firm break down barriers into more competitive export markets. This RBV approach to explaining causality running from innovation to exports is consistent with the predictions of both product-cycle models (e.g. Vernon, 1966; Krugman, 1979) as well as the more recent neo-technology models (Greenhalgh, 1990). On the other side, there are also arguments supporting the direction of causation going from exporting to innovativeness, centring on exporters' potential learning opportunities in international markets with a more diverse knowledge/technology base, which could then foster more in-house innovating activity. Again this other direction of causality is reminiscent of the RBV and in line with the theoretical predictions of global economy models of endogenous innovation and growth (e.g. Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1998).

Given the determinants outlined in Chapter 2, Chapter 3 attempts to provide an exploratory analysis of micro exporting and innovating, by bringing together and comparing in a uniform framework the impacts of various factors. Throughout the chapter, a recurring issue to address is to what extent these consequential micro activities are driven and shaped by heterogeneous firm-specific resources and capacities (especially those resources conducive to knowledge-creation activities such as size, absorptive capacity, productivity, various complementary R&D strategies, etc.), since the extant literature seems to suggest that this is a particularly vital area that can lead to a better understanding of the decision-making process underlying the firm's exporting/innovating activities. This empirical chapter employs the most appropriate establishment-level data for the UK (available at the time of writing-up this thesis), covering all market-based sectors. In investigating the determinants of exporting and R&D activities in a Heckman two-stage setting respectively, special focus has been given to the inter-linkage between exports and R&D, motivated by the literature relating internalisation to innovation.

These heterogeneous establishment-level resources have been proxied in this chapter by the use of establishment (and firm) size, productivity, capital intensity, indices of absorptive capacity for various knowledge-creation activities as well as the deployment of R&D make, buy or cooperate strategies, all of which are regarded as being reminiscent of resource advantages in overcoming the fixed costs of participating in exporting/R&D activities as well as subsequent performance. Evidence is found that all these factors have a large impact upon the propensity and/or intensity of UK establishments' exporting and/or R&D

activities, quite often with a particularly noticeable role in breaking down entry barriers to undertaking such activities.

What are particularly worth noting are the findings that confirm the establishment's R&D choices (viz. 'make', 'buy' and 'cooperate') are indeed complementary strategies: establishments that undertake in-house R&D are more likely to combine their internal and external sourcing strategies. That is, for an establishment to take advantage of knowledge acquired externally, it needs to develop internally so as to facilitate a successful assimilation of the external expertise. Indeed, all of this is reminiscent of the notion of absorptive capacity and the need for knowledge-creation and resource-building within establishments − absorptive capacity is a necessary condition for capitalising on the complementarities between internal and external resources.

In terms of the interaction between exporting and innovating activities, findings obtained show that R&D and export are indeed endogenous to each other, and thus this endogeneity needs to be controlled for when modelling such activities so as to reveal their true relationship. More specifically, (endogenous) R&D plays an important role in helping an establishment to overcome barriers to internationalisation, although conditional on having entered export markets (continuous) R&D does not further boost export intensity levels when such endogeneity between R&D and exporting is taken into account.

In light of the other direction of this relationship, in estimating R&D behaviour in an analogical econometric setting, it is found that whether an establishment engages in exports or not is not statistically significant in determining its innovative activity, once the endogenous relationship between R&D and export has been accounted for. Nevertheless, this limited impact of exporting on average could be partly attributable to the small proportion of UK establishments with exposure to international markets as well as the relatively low intensity of exporting in the UK. Indeed, if strong export orientation is used instead (measured as overseas markets being the predominant markets of production), such intense export behaviour is found to have a major impact on the establishment's R&D activity (in particular the R&D spending per unit of sales), even after controlling for the endogeneity.

Therefore, evidence from both UK manufacturing and non-manufacturing suggests that the engagement in exporting and R&D activities is important to each other. Admittedly, this is only indicative of their causal relationship; due to the cross-sectional nature of the data used, it is not possible to conduct econometric analysis and draw conclusions on the causality issue based on this data source.

Central to this export-R&D nexus is the impact of absorptive capacity (proxied by five different measures that attempt to capture various aspects of the ability to internalise external knowledge). In line with the RBV, the results obtained suggest that various absorptive capacity indices play distinct roles in deciding the business's R&D and export orientations. Most importantly, the absorptive capacity for utilising scientific knowledge stands out to have the strongest influence on exporting activity, whilst the absorptive capacity for acquiring and appropriating external knowledge appearing most important in determining R&D activity. Notably, on balance, the impact of absorptive capacity appears to be more pronounced on R&D than export, which is perhaps to some extent attributable to the way these indices are constructed (i.e. based on establishments' views on their sources of information for innovation). Meanwhile, it is reasonable to argue that the effect of absorptive capacity on the business's export behaviour is mostly indirectly through the significant and large impact of absorptive capacity on (endogenous) R&D, which then directly lowers entry barriers into international markets.

Contrary to the facilitating role of absorptive capacity, some factors rated as barriers hampering innovation also act as hindrances to establishments' exporting activity, which is intuitively appealing. However, it is worth emphasising that although some barrier variables are both significant in hindering R&D and export activities, they are more important in deterring businesses from being innovative; indeed, as with absorptive capacity, they mostly indirectly impact upon export behaviour through the R&D-export channel. This explains why when (endogenous) R&D is not significant in the export-intensity model, the barrier variables either lose their significance (in the case of manufacturing) or take an unexpected sign (non-manufacturing). Moreover, foreign ownership (particularly the US-owned) turns out to play an important role in deciding R&D and export activities for UK non-manufacturing only (vis-à-vis manufacturing).

These results need to be set against (and indeed are influenced by) the impact of the size of the establishment (representing economies-of-scale and thus the resources available within) on exporting and innovating behaviour. The size effects on both activities are broadly similarly, which take a non-linear form – a positive effect (increasing in size) on the first stage determining probability/participation decision, but a negative effect (increasing in size) on the second stage deciding intensity/how much is invested as a proportion of overall sales. In other words, a strong positive relationship is found between size and whether an establishment can overcome entry barriers to export/R&D; and an even stronger negative relationship between size and exporting/R&D intensity, conditional on the establishment having participated in exporting/R&D activity.

Particularly, taking the export-size relationship for instance, Table 3-3 shows that exporters typically only sell a (small) fraction of their produce overseas (e.g. 6.8 per cent on average), even in export-intensive industries, and this implies that those larger firms that break down barriers to exporting then take advantage of their being ‘better’ to exploit opportunities in domestic markets. Nevertheless, once the exporters have successfully established themselves on international stage (i.e. in the second stage of the model when continuous R&D is instrumented in modelling export intensity), R&D is no longer (positively) significant and the size-intensity relationship has become negative but stronger (but only after having controlled for sample selectivity using the Heckman approach[118]). Thus, in line with the RBV approach to understanding business decision to engage in export activity, establishment size plays a fundamental role in explaining exporting, and the literature suggests that what this is likely to be mirroring is the movement of larger establishments using FDI (rather than exporting) as a major means of supplying overseas markets as establishments become larger. Perhaps the important issue with regard to exporting is having an international presence, and not necessarily how much is sold abroad. Unfortunately, this thesis cannot test this hypothesis as there is no such a

[118] See Footnote 51.

variable available that measures whether the domestically producing establishment belongs to a UK-owned multinational enterprise. It is suspected that such a variable would have a crucial role in explaining (some) of the results obtained, and a suggestion is made that such an outward FDI 'marker' would be a useful addition to future surveys (either the *CIS* or the *ARD*)[119].

It is also worth noting that, in estimating the exporting model, it is found that regional effects have a different role in determining whether an establishment exports vis-à-vis how much is exported. Taking results for the manufacturing sector for instance, several regional dummies (viz. London, South West, Wales) are not significant in determining whether to enter export markets but have become significant in determining how much to export post entry. This could be interpreted as follows: being in a particular region does not guarantee the internal resources an establishment needs to expand into foreign markets (thus location does not matter so much at this initial stage). However, once it starts exporting successfully, being in particular regions is likely to intensify its export performance on this international stage, possibly due to competition effects, technological spillovers, knowledge transfers, externalities and accumulated experience within the proximity, all of which allow the improvement of technological capacity within the establishment *per se*. Indeed, scholars have outlined the notion of 'learning region' (Florida, 1995; Morgan, 1997; Boekema *et al.,* 2001), where there is sharing of diverse but overlapping technical knowledge that is tacit and embedded amid individuals and firms located in that region. As a result of this learning and resource-building process, the enhanced competence base will bring about increased competitiveness, which will then positively impact on export intensity in turn.

In terms of policy implications, the expected importance of industrial sectors in determining entry into export markets and take-up of R&D activity confirms that both trade and innovation policies benefit from being industry-specific. Secondly, given the relative importance of absorptive capacity (vis-à-vis R&D) in determining an establishment's export intensity conditional on export-market entry, policies designed to encourage investment in such capacity in order to

[119] Attempts to date to merge information from Annual Foreign Direct Investment Survey (*AFDI*) into the *ARD* have met with limited success in terms of providing an adequate dichotomy of UK enterprises into those that engage in FDI and those that do not.

improve export performance are more desirable than those that promote R&D spending alone (given also the complementarity between R&D and absorptive capacity).

However, the major implication is drawn on the importance of the size of the establishment, and its impact on both the likelihood of exporting/R&D and the relative amount spent, conditional on participation. Building up resource capabilities (which is associated with becoming larger) in order to enter export/R&D markets is the single most important determinant of this activity; but as an establishment becomes larger, policy makers need to recognise that exporting is often superseded by the establishment becoming multinational and the focus of R&D may shift from being product to process oriented; and therefore, there is no such a one-size-fits-all framework for policy making amongst differing stages of export/R&D activities.

In addition to discovering the positive influence of strong export orientation on innovation behaviour (Chapter 3), in seeking to test another embodiment of such learning effect of exporting, subsequent Chapters 4 and 5 review the relevant literature and investigate empirically whether exporting is associated with improvement in performance as measured by productivity gains; that is, whether high productivity level is a requirement of being able to export and/or whether firms become more productive when they enter export markets as a result of a 'learning-by-exporting' effect.

Chapter 4 reviews the literature on the relationship between exporting and productivity, in light of firm-level heterogeneity, in an attempt to integrate the RBV perspective into the economics literature explaining firms' exporting and learning behaviour. It is worth noting that the notion of 'productivity' is employed here not as the definitive, single characteristic to assess a firm's exporting activities; from an RBV perspective, 'productivity' serves more as a proxy for a range of firm-specific resources/characteristics that distinguish the firm from others and thus impact directly upon its performance, such as size, absorptive capacity, human/organisational capital, competence base, etc. (Baldwin and Gu, 2003).

Central to the export-productivity nexus, a major issue is whether firms that internationalise are more productive than those serving indigenous market only. The evidence in the literature on this positive association is fairly unanimous that this is indeed the case; and ample evidence summarised in Chapter 4 has confirmed the role of productivity in determining which firms export. However, the issue then becomes one of whether this is a requirement of internationalisation and/or whether firms become more productive after they have entered export markets as a result of a 'learning-by-exporting' effect. If firms have to possess certain characteristics in advance that result in higher productivity, to allow them to overcome sunk costs of entry, then 'self-selection' is likely to dominate. From an RBV perspective, the process of going international is perceived as a sequence of stages in the firm's growth trajectory, which involves substantial learning (and innovating) through internal and external channels, so as to enhance its competence base and improve its performance. Thus, the 'learning-by-exporting' proposition is consistent with the literature reviewed on internationalisation (c.f. Chapter 1, pp. 32-50), which emphasises the importance of exporting as a learning process.

The survey of the literature in Chapter 4 concludes that the extant empirical literature presents compelling evidence in favour of the firm's self-selection into the international markets, as well as evidence documenting significant contribution of exporters to aggregate productivity through the effective channel of industrial restructuring coupled with reallocations of resources; nevertheless, the findings are far less conclusive with respect to the 'learning-by-exporting' hypothesis (indeed only very limited evidence has been uncovered supporting this learning effect across countries).

Therefore, a major aim of the following empirical chapter (i.e. Chapter 5) is to use a nationally representative dataset to provide further and more extensive UK evidence on both directions of this relationship. It follows that Chapter 5 goes onto empirically assessing to what extent firm-level productivity could be further stimulated by exporting, using the weighted *FAME* data for both services and manufacturing sectors in the UK. Evaluating this linkage involves measuring the impact of productivity on the firm's preparation for entering overseas markets (i.e. the self-selectivity aspect), as well as looking at productivity effects which may occur following such entry (i.e. the 'learning-by-exporting' effect). In particular, the panel aspects of the *FAME* data are exploited when estimating appropriate econometric models, and relevant techniques are also used to ensure issues of endogeneity and sample selection are being dealt with.

From estimating probit models determining which firms exported at any time during 1996-2004, the results obtained for 14 separate UK industry groups (covering all the main marketed output sectors of the economy) confirm what most other similar studies have reported in the literature on self-selectivity. It is found that firms with higher (labour) productivity in the previous year are significantly more likely to sell overseas in the current period. Also firms that are older or that possess intangible assets (e.g. R&D stock, brand recognition, goodwill, etc.) are generally much more likely to export.

Having found that there is strong self-selection by UK firms during 1996-2004, a test is carried out to verify whether there is also a post-entry ‘learning-by-exporting’ effect associated with sales to overseas markets, using three approaches to controlling for endogeneity and sample selection: an IV model (with the age of the firm and whether it had intangible assets as the additional instruments used to control for selectivity); a control function approach (with the selectivity terms obtained from a first stage probability of exporting model included in the production function to control for bias); and a matching approach (based on the propensity scores obtained from the probability of exporting model). The results show that generally all three approaches to controlling for selectivity effects produced broadly similar results, and that ‘learning-by-exporting’ is present but it is by no means universal (even within industry groups there are differences for entrants into exporting, firms that leave exporting, and those that experienced both entry and exit into overseas markets). However, in terms of the overall estimate for the UK economy the results show that there is a substantial post-entry productivity effect for firms new to exporting; a negative effect for firms exiting overseas markets; and large productivity gains while exporting for those that both enter and exit.

More specifically, based on the preferred model (i.e. using the instrumental variable approach), findings show that for firms that are new to exporting, there is a 34% long-run increase in TFP in the year of entry, and only a small effect of around 5% in the year following entry; firms exiting overseas markets overall experience negative productivity effects in the year they stop exporting and subsequently (around a 7-8% for all the sectors covered); firms that enter and exit experience large productivity gains when they are exporting (some 19% in the year of entry, but with a 5% decline the following year).

In summary, the analysis of the export-productivity nexus presented in this chapter is novel in both approach and outcome compared with extant work for the UK. Besides weighting the data to ensure its representativeness of the population of UK firms, and having a more extensive dataset (in terms of the number of enterprises and industries covered), a dynamic GMM systems approach has also been employed to directly estimate TFP within a production function framework. Noting that there is only a limited amount of micro evidence supporting export-induced productivity growth (especially in a UK context), the analysis undertaken in Chapter 5, to the best of my knowledge, constitutes the most comprehensive assessment of the learning effect of exporting for the UK (drawing on evidence from all market-based sectors, vis-à-vis manufacturing only prevalent in previous studies), taking into account various crucial issues such as representativeness of sample, endogeneity of factor inputs and exports, sample selectivity and so on.

To recap, the main results obtained from the modelling of self-selectivity and 'learning-by-exporting' confirm that the productivity differential between exporters and non-exporters is attributable to a combination of pre-entry productivity increase (to overcome entry barriers) in all firms, and significant post-entry 'learning-by-exporting' effect in some UK industries during 1996-2004. These new and extensive results supporting a bi-directional relationship between exporting and productivity at the micro level need to be set in the context of the impact of exporting on the aggregate productivity growth in the UK. In a recent paper by Harris and Li (2008), we have examined the existence of inter-firm reallocations of resources towards more productive exporting firms, to shed light on this aggregate channel for contributing to the UK productivity by exporters. Based on a decomposition of productivity growth, we are able to show that in aggregate exporting firms experience faster productivity growth than non-exporting firms (i.e. 1.27% p.a. in terms of TFP compared to 0.8% p.a. during 1996-2004) and therefore contribute more to overall productivity growth; in contrast, most of the TFP improvement for non-exporters (around 91% of its total) is attributable to lower productivity firms exiting, rather than from internal improvements or the impact of new firms (or takeovers/mergers) having raised the average growth rate.

Consequently, to put all the analytical results relating to exporting activity into context, the findings in Chapter 5 reinforce the conclusions drawn on the review of literature on internationalisation process (Chapter 1), and resonate with the literature reviewed as well as empirical analyses undertaken with respect to the determinants of export orientation (Chapters 2 and 3). In particular, the survey of literature in Chapter 1 concludes that whether the traditional, incremental model of internationalisation is considered, or transaction-cost models (emphasising the role of sunk costs), or monopolistic-advantage models, a strong overlapping feature lies in the role and importance of firm-specific assets (e.g. complementary resources and capabilities) and knowledge accumulation. Such heterogeneous resources are proxied in Chapter 3 through the use of establishment (and firm) size, indices of absorptive capacity, productivity, R&D activity, etc., where all these factors have been found to exert a large impact on breaking down barriers to exporting for UK establishments.

In Chapter 5, only a more limited set of variables could be employed to proxy for firm-specific assets and knowledge-generating activities. Nevertheless, again there is evidence that firm size, the presence of intangible assets (such as R&D), labour productivity and the age of the firm, all have a large impact on whether exporting takes place or not. Undoubtedly, such differences rely on firms having differing knowledge and resource-bases associated with differences in rates of innovation and other aspects of TFP. Evidence also shows that sunk costs (leading to entry and exit barriers) are important to overcoming entry costs; and there is again an emphasis in the literature on firms needing an adequate knowledge-base and complementary assets/resources (especially R&D and human capital assets that lead to greater absorptive capacity) to overcome such entry barriers (Kogut and Zander, 1996), and to then benefit further when operating internationally. Hence, this naturally leads to the conclusion that the type and quality of firm-specific assets are vital in breaking down export barriers and providing sufficient absorptive capacity to benefit from learning when exporting; and whilst the literature points to various other factors that determine internationalisation (e.g. sector, networks, agglomerations, etc.), the results presented in this thesis confirm the key, central role of resources and capabilities, which is consistent with the RBV and the literature on internationalisation reviewed in Chapter 1.

As to the policy implications arising from these findings, above all, the evidence documented in Chapter 5 provides justification for the UK Government's export-promotion policies in that since exporting leads to higher productivity, it is clearly beneficial for (more) firms to sell to overseas markets to obtain both the private and public benefits from doing so (DTI, 2006). With respect to the government's role in facilitating business exporting, Hoekman and Javorcik (2004) point out a twofold role − i) to intervene in areas where there are market failures; and ii) to ensure that firms face the 'right' incentives to internationalise through strengthening innovation activity and firm capabilities which will both enable and motivate firms to overcome export-market entry costs/barriers. The authors argue that governments often fail in the latter mission by for instance, pursuing inappropriate macroeconomic policies (such as enforcing trade policies that attempt to mitigate against the short-run impacts of liberalisation but create perverse incentives for firms not to internationalise), or inappropriate microeconomic policies (such as hindering firms' entry and exit, operating inflexible labour markets). In summary, they call for the need for credibility of the overall policy stance (i.e. firms believe in the permanency of the government response to globalisation) since it impacts significantly on the incentives of firms to overcome sunk entry costs into the international markets.

In all, it could be argued that effective trade policies should consider how it might best boost participation rates in export markets through ensuring that (potential) exporters have the requisite assets (e.g. absorptive capacity and dynamic capabilities). A key issue that has featured strongly in the literature is – whether barriers to exporting are principally due to market failures or whether they are more to do with absorptive capacity and dynamic capabilities at the micro level. The evidence documented in this thesis tends to suggest that it is the characteristics of individual firms that play the major role in determining whether they can overcome entry barriers or not. Government policy to improve productivity (especially through boosting R&D and other knowledge-generating activities) helps to build up resources and improve capabilities, and thus clearly plays a role that perhaps needs to be more fully recognised when promoting exporting. Lastly, It is worth noting that the more specific issues as to what are the sources of barriers to (more) exporting, and therefore which policy initiatives have the greatest potential impact, and whether new or existing firms should be targeted, need also to be considered. Nevertheless, these issues relating to the form of assistance that governments should adopt is beyond the scope of this thesis.

Turning to the final piece of analysis of innovation activity, the last empirical chapter of this thesis (i.e. Chapter 6) attempts to provide an initial inspection of the contribution of innovation (proxied by R&D stock) to business performance (measured by productivity). This study of R&D-productivity linkage undertaken here is not as comprehensive as that regarding the export-productivity relationship. This is partly due to the fact that exporting activity is the main focus of this thesis, and also limitations of the data available to allow further analysis of the R&D activity in a panel setting. Therefore, Chapter 6 aims to provide a useful addition with respect to the productivity impact of R&D to the existing evidence pool for UK regions in the literature, utilising a new source of plant-level data on R&D for Northern Ireland.

Based on the estimation of the 'knowledge production function' separately for various manufacturing industries in Northern Ireland, the overall long-run results show that in the steady-state, R&D stock does impact positively on output in all industries (except the *textiles* sector). On the other hand, in contrast, plants without R&D spending suffer significant one-off negative productivity effects, ranging from −7% (*chemicals*) to −62% (*food & drink*). Moreover, the parameter estimates of the KPF also suggest universal returns-to-scale across all industries. Other plant-level characteristics that seem to have an impact on productivity in Northern Ireland manufacturing include ownership (i.e. being US-owned positively affects productivity in *textiles and machinery & equipment* sectors, but with a negative impact in the *rubber & plastics*; whilst being GB-owned is associated with a positive productivity effect in the m*achinery & equipment*, but a negative effect in the *clothing* sector. Single-plant enterprises have higher productivity in *food & drink* and *clothing* sectors; whilst SMEs having lower productivity in *food & drink* and *other manufacturing*. Nevertheless, the spillover effects of R&D undertaken by other businesses are found to be largely absent for Northern Ireland manufacturing, so are regional effects; on balance, age of the plant does not appear to be very important in explaining productivity differences.

In conclusion, as a distinct departure from the Neoclassical synthesis, this thesis provides a first attempt to integrate the RBV and notion of resource economy (as a new theory of IO) into the economics literature explaining firm-level behaviour (relating to resource-development and knowledge-creation) and the sustained differences observed amongst firms. The vital roles played by firm-heterogeneous resources (as embodied in size, productivity, capital intensity, absorptive capacity, R&D activities, etc.) in the firm's performance and crucial knowledge-generating activities, as well as the inter-relationships between these activities underpinned by these resources, have been both theoretically analysed and empirically examined. In particular, for the first time, a direct and comprehensive set of empirical measures have been constructed to approximate the abstract notion of absorptive capacity, capturing various dimensions to such capacities for the UK establishments.

In addition to the unique perspective this thesis offers to understand some well-studied yet still controversial issues relating to exports, innovation and productivity, other contributions of this thesis to the extant literature mainly lie in the data sources it utilises as well as methodological breakthroughs exemplified in econometric modelling of many relationships. For instance, the analyses of establishment-level exporting and innovation orientations (Chapter 3) and firm-level exporting-productivity relationship (Chapter 5) have all benefited from the deployment of nationally representative datasets (through the appropriate use of weighting technique), covering all UK market-based sectors (thus overcoming the limitations in many existing studies narrowly focusing on manufacturing sector only), which allows the analytical results to be generalised to cover the overall picture to better inform policymaking. Moreover, in investigating the above-mentioned relationships, a number of appropriate and sophisticated econometric techniques have been adopted to combat various important issues often ignored in the empirical literature, such as sample selection issues, simultaneity, endogeneity of explanatory variables and so on.

Nevertheless, the following caveats also need to be recognised for better interpretation/utilisation of the results generated in this thesis. Admittedly, as compelling as a new theory of IO, there is a high level of abstraction in the formulation of the RBV. The core underlying constituents are yet to be better defined and measured, and the specific mechanisms purported to appropriate such resources need to be more clearly detailed. In particular, despite the importance of such resource assets well-documented in this thesis, the question as to how these heterogeneous resources generate sustainable competitive advantages remains unanswered; put differently, for lack of appropriately developed analytical framework in theoretical economic models (as RBV is mostly exemplified in conceptual models developed in the strategic management literature), the processes whereby specific resources confer competitive advantage still remain very much in a black box (e.g. "the process by which absorptive capacity is developed", as argued by Lane *et al.*, 2002). As Mathews (2002) put it, "the RBV of the firm, while making some welcome progress in accounting for the heterogeneity of firms …, has nevertheless stopped short of taking its insights into the wider economy".

Meanwhile, despite the successful quantification of absorptive capacity and use of proxy for other resources (such as size, productivity, etc.) in this thesis, many particular resources (such as tacit knowledge, intangibles, various capacities) are still inherently difficult to measure and thus impossible to test empirically. In addition, this thesis primarily examines various knowledge-generating activities at the micro level with innovation being such a major activity. However, although innovative activity is most analysed in the surveys of literature, the actual empirical analysis only employs R&D as a proxy for innovative activity (and sometimes the terms of R&D and innovation are used interchangeably). Admittedly, as an input side measure, the use of R&D is limited in capturing various aspects of innovation activity, particularly where other innovation measures have differing effects. Therefore, for future research, where data permit, other measures of innovation (especially on the output side such as patents, product/process innovations) should be tried as robustness checks, also to capture a more comprehensive picture of various forms of innovative activity.

Moreover, in explaining the finding of a negative effect of establishment size on its exports volume per unit of sales (in contrast to a positive size impact on its probability of exporting), the thesis postulates that larger businesses tend to FDI (instead of exporting) as a major means of supplying overseas markets as they grow larger. Nevertheless, due to lack of information on FDI activities of UK-owned firms, this assumption cannot be directly tested. It is suspected that such a variable would have a crucial role in explaining (some) of the results obtained, and if such a FDI 'marker' could be added to future surveys, some future extension of such analysis would be possible to test this postulation.

Also in Chapter 3, despite the evidence unveiled in support of a feedback relationship between the establishment's exporting and R&D behaviour, still causality cannot be established between these two types of knowledge-generating activities due to the lack of temporal dimension to the *CIS*4 data. Nevertheless, the most up-to-date *CIS* data (i.e. *CIS*5) were collected in 2007 and have recently become available at the ONS, covering a larger number of businesses for the 2004-2006 period. Most importantly, a large number of businesses sampled in *CIS*4 have also been surveyed in *CIS*5, allowing the construction of a longitudinal dataset for direct comparison of their innovative activities and the testing of a casual relation between R&D and exports. Hence, another future avenue to pursue is to repeat the analyses undertaken in Chapter 3 in a panel of *CIS*4-*CIS*5 establishments.

Lastly, in estimating the impact of R&D stock on productivity (Chapter 6), the analysis is restricted to the Northern Ireland region only (using merged plant-level *ARD-BERD* data obtained from the DETI), due to the fact that at the time of analysis comparable GB *BERD* data were not yet available to allow a comprehensive GB-wide analysis. Now that the *BERD* data are available at the ONS (via restricted access), the analysis of R&D activity (at plant, establishment or firm level) has been made possible covering both the GB manufacturing (1994-2003) and non-manufacturing (1998-2003) sectors. Therefore, in terms of future avenues to pursue, Chapter 6 could be extended to examine the relationship between the R&D capital stock and productivity, experimenting either a similar 'knowledge production function' method and/or the 'two faces of R&D' approach that has not been utilised in Chapter 6 due to data limitations. The estimation of the 'two faces of R&D' model is expected to yield some interesting spatial insights into the R&D-productivity relationship in the GB context, as it explicitly models the process of lagging regions' catching-up with the leading region.

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