Globalization, Inflation and Monetary Policy

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Abstract

The thesis is aimed at investigating the implications of globalization for the conduct of monetary policy. By globalization we mean increased interdependence of national economies as reflected in greater and freer flow of goods, services, capital, and labour across national borders. In particular, our research addresses a number of important issues in the recent monetary policy and globalization debate. First, are global factors becoming important drivers of domestic inflation? Second, are global factors playing more powerful role on inflation dynamics in the sectors of an economy that are more open to trade? Third, has globalization made the job of Central Bankers more difficult? And finally, do the Central Bankers in the United States and the United Kingdom consider international factors too along with domestic factors while determining the short term interest rates?

Inflation rates have been observed to be low across industrial countries since the early 1990s. The co-movements of inflation rates across countries are strikingly high. We model the co-movements of inflation rates by a global factor, regional factors and idiosyncratic component. In particular, we estimate a Dynamic Factor Model with Stochastic Volatility and find that the contribution of the global factor has increased over time in explaining the variance of inflation in OECD countries. The regional factor also gains importance in countries with strong intra-regional economic linkages potentially due to proliferation of regional trade agreements and common currency areas. In the European countries, the role of global and regional factor together dominates the country specific factor since the late 1990s. The volatility of inflation has substantially decreased over time and our modelling framework incorporates time varying volatility of inflation. We find strong positive and significant relationship between the international common factor and economic globalization.

Consistent with inflation becoming a global phenomenon, co-movements of aggregate inflation between countries are observed to be high. We examine whether this is also

the case for sectoral inflation, we model the co-movements in sectoral inflation as being associated with a global factor, a sector specific factor and an idiosyncratic error term. We find that the co-movements of inflation of tradable sectors are substantially greater than the co-movements in non-tradable sectors which implies that the greater co-movements of inflation can be attributed to increased trade global integration of product markets. To test this, we attempt to find empirical relationship between the estimated common factor in sectors and openness to trade measured as import penetration. A positive relationship is found between the estimated sector specific common factors and import penetration.

Given our earlier chapters identify important global dimension to aggregate and sectoral inflation, does this matter for monetary policy? The implication of globalization for monetary policy in the United States and the United Kingdom are examined by estimating monetary policy reaction function for these advanced economies over the sample period 1985-2010. We also consider time variations in these reaction function by estimating over a sub-sample of 1992-2010 for the United Kingdom and the Greenspan-Bernanke Era for the United States. We estimate the policy reaction function with domestic and global inflation and output gaps and with the component of domestic inflation and output gap that is not related to global variations. The policy reaction function augmented with foreign variables such as real effective exchange rate and foreign interest rate is also estimated. We use measures of inflation based on GDP deflator, CPI and inflation expectations. We find that the Federal Reserve responds to global inflation only in the full sample and to global as well as the country specific inflation in the second sub-sample (Greenspan-Bernanke Era). This may imply strong commitment of the Federal Reserve to the goal of "price stability" during Greenspan-Bernanke Era. The Bank of England responds to global inflation along with the country specific inflation. The international factors such as the real effective exchange rate changes (depreciation) and foreign interest rates have significant and positive effect on policy rates.

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This thesis is dedicated to my sweet heart daughter Nabiha.

Declaration

The material contained in this thesis is my own and has not been previously submitted for a degree in this or any other University.

Signature

Kaneez Fatima

Chapter 1

Globalization of Inflation and its Implications for Monetary Policy

1.1 Introduction

This thesis aims to examine the implications of globalization for the nature of domestic inflation and for the conduct of monetary policy. Globalization is defined as increased interdependence of national economies, reflected in greater and freer flow of goods, services, capital, and labour across national borders. In particular, our research addresses several of the main issues in the recent monetary policy and globalization debate. First, are global and regional factors becoming important drivers of domestic inflation? Second, are global factors playing more powerful role on inflation dynamics in the sectors of an economy that are more open to trade? Third, can increased synchronization of inflation be associated with increased economic globalization? Fourth, has globalization made the job of Central Bankers more complicated?

It is widely believed that globalization has accelerated since the early 1990s. World markets are more integrated now than ever due to information technology revolution and deregulations in financial markets. International trade has substantially increased. Figure 1.1 highlights the trend in global trade. The world trade more than doubles in 2007 since 1961 and then decreases marginally during the Global Financial Crisis followed by an upward trend. Integration of goods market lead to low cost imports from emerging economies to developed countries, increased labour supply, increased productivity and increased competitive pressures on domestic firms. Hence, the international integration of financial, goods and services markets is highly important from a monetary policy perspective as it has changed the environment in which monetary policy operates.

Globalization affects the structure and working of financial and economic environment in which monetary policy works so the conduct of monetary policy is also influenced as the relative importance of the channels through which monetary policy transmits may change. Theory suggests that the key elements of monetary policy framework such as inflation process and transmission mechanism may be affected by the global integration of financial and goods markets through various channels. Though in the long run inflation may always and every where be a monetary phenomenon as suggested by Milton Friedman yet short and medium run dynamics of inflation are affected by globalization (Mishkin (2009)). In an integrated economic environment shocks can be easily and rapidly transmitted across borders since real linkages have implications for nominal variables.

Thus, understanding the implications of globalization for monetary policy is very important for Central Bankers. The importance of understanding the international influences on monetary policy and on the environment in which monetary policy works is emphasized by several prominent Central Bankers. For instances, Fisher (2008) notes, "*Globalization means that we can no longer guide policy by ignoring trade and capital flows or the invisible but nonetheless effective links between countries that have been forged through cyberspace*" (p.182). Once, he remarks, "*one can not make monetary policy without being aware of the forces of globalization acting upon our economy*"(Fisher (2005)). Bernanke (2007) also highlights the importance of understanding international influences on monetary policy. He states, "*Effective monetary policy making now requires taking into account a diverse set of global influences, many of which are not yet fully understood.*" Considering the importance of globalization for monetary policy, the Federal Reserve Bank of Dallas established the Globalization and Monetary Policy Institute in 2007 for the purpose of better understanding how globalization may alter the environment in which the U.S. monetary policy decisions are made.

1.2 Globalization of Inflation

Globalization may affect inflation and monetary policy through several channels. First, integration of hundreds of millions of workers from emerging countries in the world market economy and increased productivity put downward pressure on inflation which is most important variable from monetary policy perspective (Fisher (2008)). Second, globalization has reduced the monopoly power of firms and workers by increasing competition in goods and labour markets which consequently may have exerted downward pressure on margins, unit labour cost and inflation (Rogoff (2008)). Third, the global saving glut (a term coined by Bernanke (2005) suggesting that the U.S. current account deficit is by-product of an increase in global saving rate due to increased saving rate in Asia) has reduced global demand (ex ante) relative to global supply (ex ante) and hence alleviated the inflationary pressures (White (2008)). Financial globalization i.e. greater international capital mobility may have disciplinary affect through inducing central banks to conduct sound monetary policy (Spiegel (2009)).

The change in the environment in which monetary policy works has consequently made the monetary policy making more challenging. However, there are unsettled issues in the literature concerning the implications of globalization for monetary policy such as whether global trends of low and stable inflation are due to globalization or improved monetary policies in many countries. For instance, White (2008) argues that if low and stable inflation was due to prudent monetary policies then why this decline in inflation was shared by a diverse set of economies with different institutional setups and different monetary policies etc. Moreover, there is a debate on whether low exchange pass through in some countries and flattening of the Philips Curve is attributable to globalization or prudent monetary policy making. Has domestic inflation become more sensitive to foreign output gap? Should monetary policy authorities consider foreign variables while making monetary policy? (See Ball (2006), Mishkin (2009), Rogoff (2003), Fisher (2008), Borio and Filardo (2007) and Ihrig et al. (2007) among many others.)

The empirical literature investigates the impact of globalization on domestic inflation by examining several channels through which globalization may has effected inflation. It includes effects through trade channel due to import prices, increased competition, productivity, integration of labour markets and sensitivity of domestic inflation to domestic and foreign output gap. However, evidence is not conclusive. Mixed evidence on the impact of globalization on inflation and monetary policy may be partly because even most recent studies covers the time period up to the first half of 2000 whereas current wave of globalization is still fairly new. It may be difficult to detect impact of globalization on monetary policy using econometric tools based on less globalised world. Moreover, due to the fact that over last decades, economies have observed structural changes such as change in monetary policy regimes, it is difficult to separately identify the effect of globalization from other changes in economies (see Gonzalez-Paramo (2008)).[1]

Inflation rates are observed to co-move substantially in many countries during the last few decades. The episodes of high and volatile inflation during 1970s and early 1980s are commonly experienced across countries. The low and stable inflation during the last decade, which is attributed to credible monetary policies, is commonly shared by a diverse set of countries with different monetary policies, different institutional set ups, different degrees of financial and economic developments and most importantly different attitudes to exchange rate movements (White (2008)). It is documented by Wang and Wen (2007) that the domestic monetary shocks and cross country correlation in money growth do not produce the observed co-movements in inflation rates across OECD countries. Canova and Ferroni (2012) also show that the U.S. inflation dynamics are not fully explained by the monetary policy shocks. Thus, the common patterns observed in inflation process across a diverse set of countries during the last few decades call for some unified global explanation.

[1]Detailed discussion on the issue of quantifying the effects of globalization on inflation is given in the literature review chapter.

To find a unified global explanation of highly synchronized inflation rates globally, a strand of literature has developed that attempt to measure the strong linkages in inflation rates across countries to examine how globalized inflation has become. A factor or dynamic factor modelling approach is used to measure the co-movements in inflation rates across several countries. The presumption of the dynamic factor model is that the observed co-movements in a large set of time series is due to small number of unobserved common dynamic factors. The observed co-movements that are not due to a common factor are attributed to idiosyncratic shocks which are not correlated to common disturbances. Thus the model is used to identify the dynamics of time series attributable to some common factors and to idiosyncratic shocks. By extracting the common factor, inflation variance of each country is decomposed into global and country specific factors.

1.3 Monetary Policy in Global Perspective

The strong synchronization of inflation rates and to a lower extent correlation of output gap across countries have important implications for monetary policy making. Though there exists a controversy regarding the extent to which the observed comovements are attributable to globalization (see Byrne et al. (2013)), practice of common monetary policy and to common commodity price shocks, yet it is generally accepted that the global forces are important. Considering the importance of global forces, monetary policy authorities should take them into account along with domestic developments, as noted by Ciccarelli and Mojon (2010), "*The main risk of ignoring international developments is to overrate the importance of domestic developments*" (p.524).

The importance of considering international developments is highlighted by a number of Central Bankers. For instance, Smaghi (2011) notes that increasing importance of global inflation can not be ignored any longer while forecasting inflationary pressures. Bullard (2012) also stresses the importance of global output gap in case of the United States. He notes that the U.S inflation has increased recently while typical estimates show that it should have remained low during 2011 as the most measures of output gap remained very wide. The potential explanation proposed by him is that the Federal Reserve may not be weighing global conditions appropriately. The U.S. output gap is not relevant for the U.S. inflation rather it is the global output gap that matters.[2] Moreover, he argues that the global inflation might be responsible for recent increase in the U.S. prices. He argues that monetary authorities can only ignore foreign output gap when inflation is defined as "domestic (producer) price inflation" and exchange rates are perfectly flexible, the conditions which is not often met in reality.

1.4 Contribution to Literature

We contribute to the literature on global inflation and the implication of globalization for monetary policy in a number of directions.

The studies in the existing literature on inflation globalization (for example Ciccarelli and Mojon (2010), Neely and Rapach (2011) and Monacelli and Sala (2009)) assume that the volatility of inflation remains constant over time and are unable to identify the time variations in global and country specific factors.[3] However, this assumption does not seem realistic as inflation volatility has been changing over time. It is suggested by several studies such as Cecchetti et al. (2007), Cogley and Sargent (2005) and Canova and Gambetti (2009) that inflation process has significantly changed over time. This issue is addressed by Ciccarelli and Mojon (2010) and Neely and Rapach (2011) by using sub-sample analysis where sample is divided at around mid 1980s when period of great moderation started and globalization is believed to accelerate.

Given the significant shifts in the volatility of inflation over time, that is, the 1970s boom, and great moderation's bust, it is essential to take into account this aspect of the behaviour of inflation. We contribute by taking into account the time varying volatility of inflation. We model the co-movements in inflation rates of 22 OECD countries by employing the Dynamic Factor Model with Stochastic Volatility (DFM-SV), developed by Stock and Watson (2010). The aim of the model is to decompose inflation series of

[2]The other explanation, according to him, could be that output gap is not as wide as commonly supposed.
[3]Mumtaz and Surico (2012) is an exception.

22 OECD countries into a global component, regional components and an idiosyncratic component. The DFM-SV model allows for stochastic volatility in the factors and the idiosyncratic disturbance terms.

Secondly, we contribute by capturing the regional factors from inflation series.[4] Identification of regional factors in synchronization of inflation is especially important in the European countries context where several measure have been taken to strengthen the intra-regional linkages such as the formation of European Monetary System (EMS) and the creation of common currency Area. The links between countries in a region also has become stronger with implementation of similar monetary policies. We identify the regional composition of countries both endogenously and exogenously. The regions are determined endogenously using K-means clustering. Three different compositions of exogenously determined regions are also used. Purpose of using different regional compositions is to investigate the potential effects of the formation of the EMS and the Euro on regional factors. Thirdly, we contribute by finding the empirical relationship between the estimated comovements in inflation across countries and economic globalization.

Complementing the global phenomenon in aggregate inflation, it appears important to measure the co-movements in sectoral level inflation across countries. It may further help understand the sources of inflation being a global phenomenon since the extent of globalization differs across sectors. Degree of trade openness and market competitiveness differ considerably across sectors even within the same country. Hence, prices in all sectors are not affected by the global shocks in a similar fashion. The heterogeneity across sectors calls for measuring global factor using sectoral data suggesting that the sectors that are exposed to higher degree of trade openness should observe higher co-movements in inflation across countries.

We contribute to the literature by decomposing the sectoral inflation into a global factor, sector specific factors and an idiosyncratic component by employing the Dynamic Factor Model for a larger sample of countries over an extended period of 1971-2007. The global common factor captures the effect of a global shock on all sectors of all

[4]Neely and Rapach (2011) allow for regional factors but they do not take into account stochastic volatility.

countries and the sector specific factors capture the effects of shocks that affect particular sectors in all countries. This allows us to examine the co-movements in tradable and non-tradable sectors across countries.[5] We expect that the inflation in tradable sectors across countries should display higher co-movements than non-tradable sectors if increased integration of international markets is one of the responsible factors for globalization of inflation. Moreover, to test whether high co-movements in sectoral inflation across countries are associated with high degree of trade openness, we examine the relationship between the global factor, sector specific factor and sectoral trade openness. Import penetration is used as a measures of trade openness.

Increased international interdependence of economies and aggregate and sectoral inflation becoming a global phenomenon may have important implications for monetary policy. This is also emphasized by Fisher (2008) who states, "*Globalization indeed warrants the examination of broader array of data in arriving at monetary policy decisions. For example understanding global capacity utilisation in an industry may be more useful than equivalent measures of domestic capacity*"(p.185). Several studies attempt to develop monetary policy rules for open economies. Some studies develop variants of original Taylor Rule (Taylor (1993)) by incorporating global variables such as exchange rate, foreign interest rates and terms of trade gap.[6]

We contribute to the literature on Taylor type rules in international setting by augmenting the Taylor Rule with global inflation and global output gap. This is the first study that estimate the Taylor Rule in international setting augmented with global inflation and global output gap. We estimate several specifications of the Taylor Rule for the United States and the United Kingdom augmented with global inflation and global output gap and foreign variables such as real effective exchange rate and foreign interest rate. We estimate one quarter and a year forward looking Taylor Rule to examine the forward looking behaviour of the Federal Reserve and the Bank of England. To examine whether the response of Central Banks to global and domestic variables changes over time, we estimate the Taylor Rule for sub samples (Greenspan-Bernanke

[5] Though information technology revolution has weaken the barrier between the goods and services that were thought to be tradable across countries and those that were not yet distance still matter for trade in very fundamental sense (Fisher (2008)).

[6] For instance, Adam et al. (2005), Clarida et al. (2000) and Chadha et al. (2004) estimate Taylor type rules in international context.

Era i.e. 1987-2010 for the United States and Inflation Targeting Regime for the United Kingdom i.e. 1992-2010). Moreover, for robustness check, we estimate the Taylor Rule with different measures of inflation (i.e. inflation based on GDP deflator, CPI, and expected inflation).

1.5 Thesis Outline

The thesis is organised as follows.

Chapter two reviews in detail the related literature on inflation globalization and monetary policy. In Chapter Three we measure the co-movements in aggregate inflation of 22 OECD countries using the Dynamic Factor Model with Stochastic Volatility (DFM-SV). In the DFM-SV model, inflation is a function of a global factor, regional factors, and a country specific component. For the regional factors, we estimate the composition of the regions both endogenously and exogenously. For endogenous composition of regions, we apply K-means clustering to estimate regions after extracting the global component from the inflation series. Three different exogenously determined compositions of regions are used to test whether regional composition has any effect on the importance of regional factor in explaining the variance of inflation. We estimate the Dynamic Factor Model in two steps. First, with constant disturbance variances over the two split sub samples (1961-1982 and 1983-2008) and then estimate DFM-SV model. We split the sample at 1983 as it coincide with the U.S. experience of Volckers disinflation, profound monetary policy changes in many countries in our sample and a subsequent era of overall low macro economic volatility known as Great Moderation. Moreover, to examine the effects of the formation of the EMS and the Euro, sample period is also split at 1979 (1961-1979 and 1980-2008) and at 1999 (1961-1999 and 2000-2008). To investigate source of international synchronization of inflation, an empirical relationship between the estimated international factor (the global and regional) and economic globalization is estimated.

Chapter 4 examines the co-movements in sectoral inflation data of 15 sectors for 15

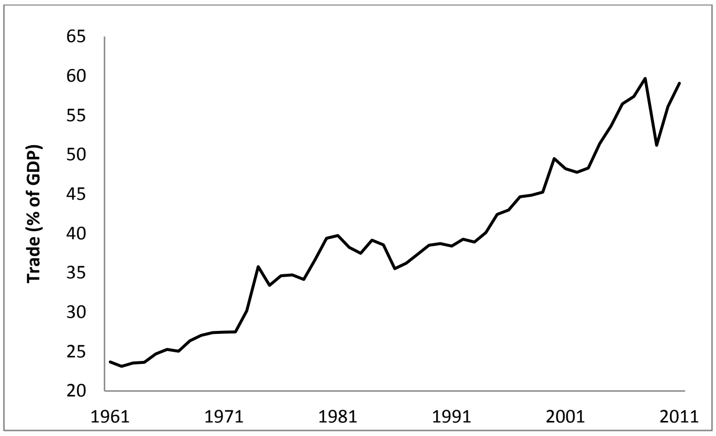
OECD countries. Sectoral inflation is decomposed into a global factor, sector specific factor and an idiosyncratic component. The global common factor captures the effect of a global shock on all sectors of all countries and the sector specific factors capture the effects of shocks that affect particular sectors in all countries. We compare the global and sector specific factors in sectors that are considered as tradables to those that are classified as non-tradables. The relationship between openness to trade and the common factor in sectors across countries is examined where import penetration is used as a measure of trade openness.

Chapter 5 is aimed to investigate whether domestic monetary policy functions are influenced by global variables. We estimate the Taylor Rule augmented with global inflation, global output gap and foreign variables (i.e. interest rate of foreign country and real effective exchange rate). The global output gap and inflation are computed as the weighted average output gap and inflation of twenty larger trading partners of the United States and the United Kingdom where the weights are given as the sum of exports and imports of each country with the U.S. (U.K.) as a fraction of total U.S.(U.K) exports and imports with a set of countries. We use GMM since it is a preferred estimation technique to OLS as it does not require information about the exact distribution of the error term and takes into account the possible correlation between independent variables and the residuals by using the appropriate instruments. Furthermore, the Taylor Rule is estimated for sub samples (Greenspan-Bernanke Era for the United States and Inflation Targeting regime for the United Kingdom). For robustness check the reaction functions are re-estimated using inflation measures based on CPI and expected inflation.

Chapter 6 provides concluding remarks.

To preview our main findings, inflation is globalized at aggregate and sectoral level. The countries and the sectors which are more open to trade and more globalized economically observe high international synchronization of inflation. The international synchronized of inflation can be attributed to economic globalization. Time varying volatility of inflation matters and should be taken into account. The Federal Reserve and the Bank of England react to international variables. Thus, it suggests that given the high interdependence of national economies, monetary policy authorities should keep in view the global perspective while taking policy decisions.

Figure 1.1: Trend in global trade (percentage of GDP)



Notes: The figure shows trend in the world trade. The data is obtained from the World Bank national accounts data, UK Data Service.

Chapter 2

Literature Review

The implication of globalization for monetary policy has been a subject of great interest in the monetary policy literature since the turn of the century. The different channels through which globalization is affecting key elements of the monetary policy framework, such as the inflation process and the monetary policy transmission mechanism are being investigated and analysed both empirically and theoretically and the literature is still growing. Several issues has been raised and investigated on the implications of globalization on monetary policy. The main issue is how monetary policy should be conducted in the circumstances in which the national economies have become interdependent due to increased integration of goods, services and financial markets. The globalization of financial markets and inflation are two important channels through which globalization may have affected the transmission mechanism and effectiveness of monetary policy. In the first instance, monetary policy works by affecting the conditions in financial markets, including the levels of interest rate and asset prices. The debate whether the ability of monetary policy to influence the conditions in domestic financial market is deteriorated in the environment of tightly integrated financial markets is not over yet. Secondly, inflation, which is a key goal variable from monetary policy perspective is influenced by international factors through various channels. We will explore in this section what the theoretical and empirical literature tells us about the impact of globalization on inflation and its implications for monetary policy.

This Chapter is set out as follows. Section 2.1 reviews the literature on the impact of financial globalization on monetary policy. Section 2.2 reviews impact of globalization on domestic inflation. Section 2.3 discusses the literature on globalization of inflation. In Section 2.4 monetary policy in global perspective is reviewed.

2.1 Impact of Financial Globalization on Monetary Policy

To understand the mechanism through which globalization may affect the inflation process and monetary policy, it would be helpful to have some background knowledge of how global forces affect financial markets as monetary policy works through financial markets at the first stage.

Monetary policy actions transmit into the real economy through various channels.[1] Working through channels, monetary policy affects the conditions in financial markets at first stage. The financial environment in which monetary policy was made has been changed and become complicated by the international integration of financial markets. International integration of financial markets is termed as financial globalization. This definition implies increased cross border capital flows and trade in financial assets in a financially global world. The size of international capital flows and trade in financial assets has increased substantially over the last decade. The global nature of financial markets has created a favourable field for the growth of financial innovations which in turn made the financial markets more tightly integrated and complicated. For the United States, as Bernanke (2007) states in a speech,

"*foreigners hold about one quarter of the long term fixed income securities issued by U.S. entities of all types and more than half of publicly held U.S. securities. Cross border financial flows are enormous and growing: For example , in 2006 foreigners acquire on net more than 1.6 trillion Dollars in U.S. assets, while U.S. investors purchased more than 1 trillion Dollars in foreign assets.*"

[1] The main channels identified in the literature include the interest rate channel, exchange rate channel, asset price channel and credit markets channel (see for exampleMishkin (1995)).

Papademos (2007) mentioned in his speech that financial globalization measure as the sum of stocks of foreign assets and foreign liabilities of the total economy as a percentage of GDP, has increased threefold in advanced economies between the early 1990s and 2004 and in the Euro Area alone, the sum of outstanding foreign assets and liabilities has increased from 190 percent of GDP to in 1999 to 280 percent in 2005.

Another statistical indicator of financial globalization is a measure of correlation between financial variables in different countries. High correlation between short and long term interest rates and asset prices indicates higher financial globalization. The literature shows that the correlations between the variables in financial markets have been increased with increased financial interdependence. Bernanke (2007) quotes an example for the United States that the average daily correlation between changes in ten year swap rates in the United States and Germany was 0.42 (during 1990-2006) that raised to 0.65 during last three years of period (2003-2006). A recent rise in correlation between bond yields in the United States and other countries such as Japan, Canada, Germany and the United Kingdom is also documented by Kamin (2010).[2] High co-movements between financial variables stem from the increasing spillovers of national financial markets to other countries. Several studies document significant spillovers between national bond markets, however, the evidence of an increase in the spillovers with increased globalization is rather mixed. A plausible explanation of highly correlated long term interest rate and key asset prices is proposed by Bernanke (2007). He noted that may be the economic shocks, for example oil price shock, has become global in nature due to increased economic integration and the central banks respond these shocks in similar ways. [3] Alternatively co-movements of nominal long term bond yields could be due to underlying co-movements of inflation expectation (Fisher hypothesis).

In a global financial environment, job of monetary policy makers has become more challenging. They may need to take into account international developments too while

[2]Ferguson (2005) also noted increasing average correlation of monthly equity market index returns among the United States, the United Kingdom, France, and Germany. It was around 0.1 from the end of World War II to 1971, 0.5 from 1972 to 2000, and since 2000, it rose to 0.8.

[3]Evidence of significant cross-border spillovers in bond yields among the united States and other advanced economies is given by Chinn and Frankel (2003), Ehrmann et al. (2005) and Bayoumi and Swiston (2007). Boivin and Giannoni (2008) showed that foreign developments explain a considerable fraction of variance in macroeconomic variables including the federal fund rate and long term yields in the United States over 1984-2005 period. For the mixed evidence on the role of globalization for significant cross border spillovers, Kamin (2010) explains that it is may be due to the fact that many studies focus on developed economies that were already well integrated several decades ago.

taking monetary policy decisions. Integration of financial markets may affect the transmission of monetary policy by making some channels more important and some others less so, as opposed to the case in the past with less integrated financial markets. Monetary policy works through control of short term interest rates.[4] Changes in short term interest rate influence the conditions in financial markets by affecting long term interest rates, the supply of bank loans, the levels of equity and asset prices, and exchange rate. The expectation theory of term structure states that long term interest rates represent the average of expected future short term interest rates.[5] However, a risk premium is also incorporated in long term interest rates which is influenced by external shocks. Thus, in internationally integrated financial markets the responsiveness of long term interest rate and prices of long term assets to short term interest rate may decline because of influence of international market conditions on long term interest rates. Does this imply that monetary policy has lost its effectiveness under financial globalization?

The debate is not settled and the literature is growing on the issue especially after the financial crisis of 2007. Some authors argue that ability of central banks to control monetary policy is affected with the increased financial globalization. For instance, Rogoff (2006) claims that even the larger central banks have less direct control over medium to long term interest rate now than might have been the case earlier with less integrated financial markets. Bernanke (2007) acknowledges that financial globalization has raised difficulties for monetary policy as the analysis of financial and economic conditions has become complex. He notes that the Treasury Yield Curve is being inverted by increased foreign demand for the U.S. financial assets therefore the Federal Reserve must take into account the various effects of foreign capital inflows on U.S. yields and asset prices.[6] However, he argues that though the link between monetary policy actions and long term interest rates is looser than to those short term interest rates,[7] the Federal Reserve can make this link strong by consistent and predictable

[4]Interest rate channel of monetary policy transmission mechanism is traditional and often regarded as the main channel (Taylor (1995)).

[5]We will discuss later whether decisions on short run interest rate determination are influenced by international factors.

[6]The Treasury Yield Curve inverted as the long term interest rates were lower than the short term interest rate. This was due to reduced term premium because of strong foreign demand of the U.S. long term debt.

[7]This is also documented by Kamin (2010) who notes in his analysis on financial globalization and monetary policy that integration of financial markets is increasing the effect of foreign factors on yield of long term assets. He showed that though the ability of monetary policy to affect long term interest rate through changes in short term interest rate is not deteriorated with increased financial globalization, yet the share of variations in long term interest rate explained by short term interest rate has declined over time. For small and medium size economies such as Canada, Sweden. Switzerland and United Kingdom, Gudmundsson (2008) showed that the effect of policy rate changes on long term

policies. Thus the financial globalization does not reduce the ability of the Federal Reserve to influence financial conditions (Bernanke (2007)).

The implication of financial globalization for monetary policy transmission is examined by Woodford (2010). He uses a simple version of model proposed by Clarida et al. (2002) where interest rates are equal across countries. He shows that financial openness does not affect the ability of given monetary policy to influence domestic aggregate demand and domestic inflation dynamics. He concludes that globalization of even higher degree than has been observed, can not impair the control of the domestic monetary policy by a central bank. However, Meier (2012) argues that model used by Woodford (2010) is not suited to analyse the impact of financial globalization on monetary policy. He uses a variant of Gali (2008)'s baseline New Keynesian model, modified to allow for international trading in multiple assets and subject to financial frictions. He analysed two different forms of integration i.e. an increase in the level of gross foreign asset holdings and a decrease in the cost of international asset trading. He argues that financial integration has different affects on the monetary policy transmission mechanism. Some effects are positive while some are negative which cancel out each other and overall monetary policy's effectiveness is not eroded by financial integration. However, he shows that though financial globalization does not undermine the effectiveness of monetary policy yet it affects the relative importance of the monetary policy transmission channels (the exchange rate channel and wealth channel is strengthened and the interest rate channel is weakened).

Financial integration has another potential important implication for monetary policy i.e. it could have disciplining effect on monetary policy. Spiegel (2009), for example, argues that reliance of Governments on inflation tax as a source of revenue decreases as financial globalization provides investors a choice of international substitutable assets. Investors can move their funds very easily from one currency to other to avoid depreciation resulted from high inflation. Thus it makes very costly for central banks to deviate from goal of price stability. Kose et al. (2006) argued that superior monetary policy is one of the primary, "collateral benefits" gained from financial globalization.

interest rates have become weaker over time from 1990 to 2006.

Monetary policy makers such as Ferguson (2005), kroszner (2007) and Fisher (2008) also noted in their speeches that financial globalization has a disciplinary effect on monetary policy and as a result performance of monetary policy has been improved.[8]

2.2 Impact of Globalization on Domestic Inflation

It has been observed that inflation rates across the globe are highly correlated especially in the OECD countries. Several studies, such as Ciccarelli and Mojon (2010), Mumtaz and Surico (2012), and Monacelli and Sala (2009) among others documented strikingly high co-movements in inflation rates across the globe. We aim to explore this strand of literature to examine if inflation has become a global phenomenon. To have an insight of common inflation movements internationally, it is important to know what theory and empirical evidence tell us about the propagation of international shocks into domestic inflation. Inflation is exposed to international shocks through various direct and indirect channels. They include effects through openness to trade, import prices and stronger international competition in product and labour markets. Moreover, the effect of globalization on inflation is widely examined by measuring the sensitivity of domestic inflation to foreign demand conditions with the argument that increased integration may have changed the inflation dynamics and its formation mechanism. We will briefly review the theoretical literature and empirical evidence on the impact of globalization on domestic inflation.

2.2.1 Trade Effect Due to Import Prices

The expansion of international trade especially the low cost imports to developed countries from China and other developing countries may have direct and indirect effect on domestic prices and inflation. The direct impact of low cost imports is via production process and consumption. The cheap imports put downward pressure on domestic prices by entering in the production process as inputs and in the consumer basket as

[8]Some other authors such as Obstfeld (1998) and Tytell and Wei (2006) also emphasize on the potential disciplinary effect of financial integration on monetary policy.

final goods. However, this downward pressure on domestic prices is offset to some extent, as low prices enhance purchasing power of consumer who use it to buy other products, putting upward pressure on their prices (Fisher (2008)) The indirect impact is through increased competition. This affects the pricing decisions of the domestic firms which produce the products that are close substitute to imported goods and for the firms which use imports as inputs in their production. Rogoff (2003) noted that competition not only put a downward pressure on prices, it also makes prices and wages more flexible. The flexible prices and wages reduces the real effects of unanticipated monetary policy, hence leaving less cause for central bank to increase inflation. Thus globalization enhances competition which in turn increases anti-inflation credibility of central bank.

A significant amount of work on globalization and inflation has tried to measure the effect of low cost import prices on domestic prices. The empirical literature has particularly emphasized on measuring the impact of import prices on domestic prices and addressed the question that to what extent the developments in import prices are due to globalization. Gamber and Hung (2001) measured the impact of import prices on the sectoral prices in the U.S. and found that prices in the industries which are faced with greater import penetration have greater import price effect. Koske et al. (2010) estimated the direct and indirect impact of import prices on domestic price. They found that the impact of import prices on consumer prices has become increasingly important since the mid 1990s and significant indirect impact of import prices on domestic prices due to increased competition from lower price imports. An evidence of modest but statistically significant impact of low cost imports from China on the U.S. import prices is reported by Kamin et al. (2006). A comprehensive study by IMF (2006), which used an augmented Philips Curve[9] to estimate the direct effect of globalization on inflation through import prices, noted a small impact of import prices on inflation in industrial economies.[10] The IMF (2006) paper found that lower import prices in-

[9]The Philips Curve is a relationship between inflation and output gap. The original Philips Curve suggested a trade-off between the rate of unemployment and wage inflation. Later Friedman (1968) argued that there exists no inflation-unemployment trade-off in the long run. He suggested for an inflation expectation augmented Philips Curve which is vertical in the long run. The modern approach to Philips Curve is the New Keynesian Phillips Curve (NKPC) which is derived from a micro-founded model. The NKPC states that inflation is a function of next period's expected inflation rate and the gap between the frictionless optimal price level(fixed markup plus marginal cost) and the current price level.

[10]The paper showed that in the late 1990s, import prices contributed to disinflation by 1 percentage point on annual average in the U.S. and by 0.5 percentage point in other seven industrial economies.

directly affected inflation by restraining domestic firm's prices in face of competition from imports in a number of industrial economies. The effect was larger for the firms with greater import penetration. Peacock and Baumann (2008) investigated whether the post-war inflation movements in the U.S., the U.K. and Japan can be explained by import price. They found that import prices do help explain the dynamics of inflation. However they suggested that impact of import prices in firm's marginal cost remain constant since the mid 1980s with the exception of the U.K. that showed an increase in importance of import prices in firm's marginal cost. Kohn (2006) estimated that import prices had a depressing impact of 0.5-1 percentage point on the U.S. inflation during 2000-2005. Ihrig et al. (2007) documented a weak evidence on impact of import prices on inflation.

The effects of globalization on domestic inflation through import prices is not unidirectional. Increased international trade is associated with high productivity growth in emerging economies such as China and India. The high demand for raw materials from these countries put upward pressure on industrial commodity prices.[11] The rise in commodity prices due to high growth in developing countries has been a source of upward pressure on inflation in the United States and other industrial countries (Bernanke (2007)). Koske et al. (2010) attempted to measure the effect of strong growth in non-OECD countries on the growth of real oil and metal prices over time period 2000-2005. They estimated that if non-OECD countries had grown at the same rate as OECD countries since 2000 then by 2005 real oil and metal prices has been 40 and 10 percent lower respectively than they actually were. Guilloux and Kharroubi (2008) also took this aspect into account and examined the effect of commodity and non-commodity imports on inflation separately. They concluded that the impact of import price inflation on CPI inflation is low and to a large extent independent of actual openness.

The effects of globalization on domestic inflation can run in either direction depending upon the interaction of offsetting effects of globalization as discussed above. However, the effects of globalization on commodity and manufacture prices are important and has important implication for monetary policy. Central Banks need to monitor the

[11]Bernanke (2007) noted in his speech that China alone contributed to nearly one-third of the growth in both global real GDP and oil consumption during 2003-2005.

influences of international developments on inflation process. Fisher (2008) noted that with the persistent increase in commodity prices due to high growth rate of emerging economies has raised serious question for central banks about traditional measure of core inflation and made it difficult to separate the signal from noise in inflation data.

2.2.2 Impact Through Competition and Labour Markets

Globalization may have an indirect effect on the inflation process through increased competition, lower mark-ups and reduced pricing power of firms. The integration of world markets has indeed increased international trade, import penetration and competition. Economic theory says that increased competition refrains producers to rise prices as a result of increased demand or cost pressures as it will result in loss of market share. To remain competitive, firms have to reduce their mark-ups or raise productivity and cut costs. Thus the reduced pricing power of firms, increased productivity and decline in relative costs put a downward pressure on inflation.

Several authors have examined the effect of globalization on inflation dynamics empirically and strengthen the presumption of the role of globalization in lowering inflation worldwide. Chen et al. (2004) suggest that significantly reduced mark-ups of price over cost may be attributed to higher competition due to increased openness to trade. Duca and VanHoose (2000) show that increased competition in goods market lowered inflation and flattened the Philips Curve, making aggregate prices less sensitive to aggregate demand shocks in a multi-sector economy. Cavelaars (2003) uses mark-up as a proxy for product market competition and shows that a higher degree product market competition leads to permanent lower inflation. Similar findings and suggestions are given in the extensive studies by IMF (2006) and Koske et al. (2010). IMF (2006) show that changes in relative producer prices in certain sectors are negatively related to that sector's openness to trade. Koske et al. (2010) note that in industries with greater import penetration in OECD economies, domestic producers faced pressure to lower the mark-ups of prices over domestic costs due to competition from lower priced imports. White (2008) show that the greater competition by emerging market economies producers in goods markets has forced domestic firms in industrial countries to lower their costs. Binici et al. (2012) use sectoral inflation data for OECD countries and show that globalization affects inflation through competitiveness and productivity channels. However, Kohn (2006) argues that presumption of lower prices due to lower mark-ups in face of increased competition was not consistent with the rise in profit rates by that time. Bowman (2003) found little evidence in favour of increased competition and decreased mark-ups in industrial economies.

Globalization of labour markets may affect the inflation dynamics. The increased labour supply, high productivity and increased competition associated with globalization has affected labour markets in number of ways. It has potentially restrained unit labour cost, made the wage more flexible and reduced the negotiating power of labour unions as producers can easily choose to off-shore their business for cheap labour. Consequently, the non-accelerating inflation rate of unemployment (NAIRU) may fall.

The global labour supply has been considerably increased with increased globalization. The integration of China, India and ex-Soviet Block has increased the availability of world labour force from 1.5 billion to 3 billion (Freeman (2007)). In the United States the number of working males increased by 11 percent during 1980-2000.[12] In Europe, after the collapse of the communist regime in central and Eastern Europe, the annual average ratio of immigration to domestic population has potentially doubled (White (2008)). Nickell (2007) put that in developed OECD countries such as Austria, Spain and Switzerland, net annual immigration flow are more than 0.5 percent of the population. He surveyed the recent literature on the impact of immigration on inflation and conclude that debate is unsettled and evidence is rather mixed. Nevertheless, he noted that a rise in immigration had effectively reduced the equilibrium unemployment rate in the long run. In case of Spain, overall unemployment rate has been reduced by almost 7 percent without inflationary consequences. The inflationary pressures are also reduced in the United Kingdom as a result of rise in immigration followed by the enlargement of the European Union (Blanchflower et al. (2007)).

[12]Wynne and Kersting (2007) noted that immigrants accounted for almost 6 percent of the U.S. population in 1960 that increased to almost 13 percent in 2005.

2.2.3 Sensitivity of Domestic Prices to Domestic and Foreign Output Gaps

The most important implication of globalization for monetary policy authorities is that foreign developments may have become more important than domestic factors. As we have already discussed that increased competition, productivity and labour supply due to increased openness limit the power of domestic firms to raise prices, the domestic prices are likely to be affected to a great extent by international factors. Thus the sensitivity of domestic inflation to foreign factors may has increased and decreased to domestic factors. This effect of globalization is studied in literature by examining the sensitivity of inflation to domestic and output gap using variants of Philips Curve i.e. a standard analyses of the link between inflation and output gap.

Several studies examine whether the role of foreign capacity utilisation has increased as a determinant of domestic inflation. This hypothesis is tested by estimating a standard Phillips Curve augmented with some explanatory variables as a measure of globalization. Tootell (1998) estimated standard Phillips Curve model for the United States over the period of 1973-1996 augmented with trade-weighted measure of foreign resource utilisation (both unemployment and output gap) for G-7 trading partners of the U.S. He found that the foreign output gap does not have any role as a determinant of the United States inflation. Gamber and Hung (2001) also estimate a Phillips Curve model for the United States over a similar period 1976-1999. They augment the model with a trade-weighted average of capacity utilisation for thirty five U.S trading partners. They find a significant and positive effect of foreign capacity utilisation on the U.S inflation. The interesting result of Gamber and Hung (2001)'s research is that when they estimate Phillips Curve by including foreign capacity utilisation, the difference between actual inflation and predicted inflation based on the traditional Phillips Curve disappears since 1994. Tootell (1998)'s model is extended by Wynne and Kersting (2007) and they find evidence in favour of the role of foreign resource utilisation in the determination of inflation. This reflects that the global forces has become important only recently with increased globalization. Moreover, they examine the correlation between the U.S. inflation and world output gap where the world output gap is constructed by weighted average of output gaps of major trading partners of the

United States, sharing more than 80 percent of U.S. imports. They report a positive correlation between inflation and global output gap.

Borio and Filardo (2007) provide the broadest and more robust evidence for the rising role of global slack in the determination of inflation. They estimate the Phillips Curve model for 16 advanced economies and the Euro Area. To measure the global slack they add the information for 12 emerging market economies. They use five different versions of global output gap: a trade (exports plus imports) weighted gap, an import weighted gap, an exchange rate weighted gap, a mix of trade and exchange rate weighted gap and global GDP weighted gap to measure global slack. They estimate the augmented Phillips Curve for individual countries and for a time-series cross country panel and find that weighted average foreign output gap has positive and significant effect on domestic inflation and to be rising over time. They check the robustness of the results by including import prices and unit labour costs in equation as explanatory variable which verify their earlier findings that foreign output gap has positive effect on domestic inflation.

By contrast, a number of studies find no or marginal role of foreign output gap as a determinant of domestic inflation. For instance, Ihrig et al. (2007) reproduce the estimation used by Borio and Filardo (2007) for 14 industrial economies. They show that results of Borio and Filardo (2007) are not robust to alternate measures of foreign output gap. Their estimations with alternate measures of output gap show that the foreign output gap appears to be important in only five out of 14 industrial economies. Ball (2006) uses the data from Ihrig et al. (2007) and estimates the Phillips Curve for 14 industrial countries by pooling annual data for all countries over period 1985-2005. He finds that foreign output gap is barely significant while domestic output gap is highly significant suggesting that foreign output gaps are at most a secondary influence on inflation. Koske et al. (2010) use an error correction model to allow for a potential effect of measures of globalization on price levels instead of augmented Phillips Curve. They use a large set of 21 OECD countries over a period of 1980-2005 and find that world output gap does not have any significant effect on domestic consumer price inflation. Calza (2009) follows Tootell (1998) to test the global output hypothesis by estimating different specifications of Phillips Curve augmented by foreign output gaps for the Euro Area. He measures the foreign output gap by giving trade weights derived from bilateral trade statistics and weights based on purchasing power parity to aggregate output of 25 foreign economies. He finds very limited evidence that foreign output gap has any explanatory or predictive power for domestic inflation. Hooper et al. (2006) find that the aggregate output gap of OECD does not effect the U.S. inflation.

In principle, an increased role of the foreign output gap as a determinant of domestic inflation should imply a decreased sensitivity of domestic inflation to domestic output gap. The decreased degree of sensitivity of domestic inflation to domestic factors suggests that the slope of the Phillips curve has been changed. It is argued in the literature that the Philips Curve has become flatter.[13] A flatter Philips Curve means that for a given degree of inflation persistence, decrease in inflation involves a higher sacrifice ratio. In other words as Mishkin (2007) notes that a flatter Philips Curve implies a smaller increase in inflation in an overheated economy. Evidence on the flattening of Phillips Curve is abundant in industrial economies.[14] However, flattening of the Phillips curve is attributed to better monetary policy by some studies while others link it to increased globalization.[15]

The empirical evidence on the weakened relationship between domestic inflation and domestic output gap is not conclusive. IMF (2006) estimates a Philips Curve model using aggregate and sectoral data for a panel of eight countries (the G7 countries and Australia) over the period 1960 to 2004. To account for the impact of globalization while examining the effect of domestic output on inflation, an interaction term is introduced, the output gap being interacted with trade openness (measured as a share of non oil trade in GDP), monetary credibility, average inflation, and a wage bargaining index. They conclude that sensitivity of inflation to domestic output has decreased since the 1980s and the key factor behind the reduced sensitivity of prices to output

[13]However, by contrast Rogoff (2003) argues that increased international competition should steepen the Phillips Curve in principle instead of flattening it. As the cost of keeping prices at wrong level increases due to increase in competitive pressures arising from globalization and firms change prices frequently.

[14]For example Gali and T.Monacelli (2005) show in their small open economy model that the more open an economy is and more substitutable foreign goods are available for domestic goods, the lower is the coefficient on domestic output gap. Other prominent studies are Benati (2005), Roberts (2006), Williams (2006), IMF (2006), Borio and Filardo (2007) and Koske et al. (2010).

[15]Roberts (2006), Williams (2006) and Boivin and Giannoni (2008) link flattening of the Phillips curve to better monetary policy while Borio and Filardo (2007) and IMF (2006) attribute it to globalization factor.

is found to be trade openness. Similar findings are reported by Koske et al. (2010), who find that the impact of the domestic output gap on inflation in OECD countries has decreased since 1995. Borio and Filardo (2007) argue that there is a link between increased globalization and flattening of Phillips Curve. In empirical analysis they show that the effect of domestic output gap on the deviation of inflation from its trend is significantly reduced in 17 economies since 1992. Loungani et al. (2001) show that the Philips Curve is flatter in the countries which are more open to international capital flows than the ones with more capital controls. Dexter et al. (2005) estimate a Phillips Curve equation for the United States and show that once measures of trade are included in equation, measure of domestic output gap regain its ability to explain inflation in recent years. Gnan and Valderama (2006) also note that the link between domestic output gap and inflation has been weakened with increased globalization in the Euro Area.

There are other studies which do not find evidence from a theoretical and empirical perspective that the link between domestic output gap and inflation is affected by globalization. For instance, Ball (2006) does not agree with the argument that globalization has effected the inflation process. He argues that even in greater international competition, a firm's marginal cost depends on the firm's own level of output rather than global ones. Therefore, globalization has neither reduced the long run inflation nor has it affected the structure of the inflation process. He estimates a Phillips Curve for the panel of G7 countries over a period of 1971-2005. To allow for the effect of globalization, he introduces an interaction term between the domestic output gap and the share of trade in GDP. The results show that the effect is of marginal statistical significance. Ihrig et al. (2007) also estimate a Phillips Curve by including an interaction term between the domestic output gap and the extent of trade openness for 11 countries. The extent of trade openness is measured by the share of trade (exports plus imports) in total GDP. They find the coefficient on the interaction term is negative but small and not statistically significant implying that decline in sensitivity of inflation to domestic output gap is not due to globalization. Pehnelt (2007) also does not find that the relationship between changes in unemployment rate and domestic inflation has weakened. Woodford (2010) addresses the effect of globalization from a theoretical perspective in a two-country New Keynesian Model. He takes into consideration financial, goods and factor market integration and concludes that the slope of Phillips Curve is not reduced by global integration (even in a single world market of labour) and global slack has no role in determination of supply side inflationary pressure in an open economy model. Wynne and Kersting (2007) estimate a simple Phillips Curve model to examine the relationship between the slope of Phillips Curve and openness-measured by the share of imports in GDP and find no relationship.

Lending support to sceptical opinion on the inflation-globalization nexus Martinez-Garcia and Wynne (2010) argue that the empirical evidence on role of globalization in inflation dynamics is mixed because the models used in literature may suffer from misspecification and measures of output gaps are not consistent with theoretical concept of output gap. They analyse role of global and domestic output gap in domestic inflation dynamics using a variant of Clarida et al. (2002) model. They conclude that foreign output gap is important along with the domestic output gap for domestic inflation dynamics as long as the consumer price index is derived from the consumption basket that contains foreign goods. The more important are the foreign goods in consumption basket, more the foreign output gap will matter for domestic inflation. They find that the effects of foreign output gaps can be fully captured by the information contained in terms of trade.

The review of the literature shows that though there are strong reasons to believe that globalization has altered the short run inflation dynamics, yet the debate on the issue is not conclusive and the existing empirical evidence, in particular is mixed. It seems challenging to quantify the effects of globalization on inflation dynamics and build a general consensus on the issue when there exist overriding issues regarding computing global variables. Modest changes in assembling data for measuring globalization produce different results.[16] Martinez-Garcia and Wynne (2010) argue that despite the fact that globalization has fundamentally changed the short run inflation process, empirical evidence is mixed because the reduced form empirical models that are estimated may have been misspecified or suffer from omitted variable bias. Moreover, there are

[16] For instance the measures of globalization used by Borio and Filardo (2007) and Ihrig et al. (2007) produce different results.

reported difficulties and challenges in measuring the output gaps. Critics suggest that conventional measures of output gaps have little relationship with theoretical concept of output gaps.[17] Bullard (2012) states in his speech that if measuring domestic output gaps are difficult, then global output gaps are even harder to measure.

2.3 Globalization of Inflation

The above section explored how global forces can affect the domestic inflation process. Mixed empirical evidence on the role of these channels suggest to explore another strand of literature, i.e. measuring co-movements of inflation rates across the world. Inflation rates have been observed to be moving together around the world.[18] There must be some global forces which are driving the inflation rates to move together especially in industrial economies. The strikingly high correlation in inflation rates around the world implies that inflation has become a global phenomenon. This is documented by Ciccarelli and Mojon (2010) who quantify the global inflation using static factor model and note that almost 70 percent of the variations in inflation in OECD countries are explained by a common factor.

The potential candidates for explaining inflation as being a global phenomenon are co-movements in real activities (such as output gap, investment and consumption), common shocks to demand and supply forces, similarities in monetary policy functions and responses to common shocks, and increased integration of economies. For instance Backus et al. (1992), Kose et al. (2003), Bagliano and Morana (2009), Wang and Wen (2007) document that real economic activity tend to move together across industrial economies. However, Henriksen et al. (2011), Bagliano and Morana (2009), Eickmeier and Moll (2009) and Wang and Wen (2007) note that the co-movements in inflation rates are substantially higher than the co-movements among real output. Common demand, supply and monetary shocks also can generate strong co-movements in inflation rates across countries. Ciccarelli and Mojon (2010) show in their study that

[17] See Martinez-Garcia and Wynne (2010)for explanation.

[18] The common trends in inflation around the world, in particular across the industrial economies, are pointed out by the prominent economists such as Rogoff (2003), Levin and Piger (2004) and Wang and Wen (2007).

their measure of global inflation responds to global real activity, commodity prices and global monetary variables.

The co-movements in real activity and money aggregates do not fully explain the high co-movements in inflation rates across counties.[19] Henriksen et al. (2011), however, use an international business cycle augmented with nominal assets and a monetary authority in each country following a simple Taylor Rule. They show that a domestic technology shock does not only affect current and future productivity in the domestic economy. Instead, it does also affect future productivity in foreign economy due to spillovers of technology shocks across countries. Thus, future output in the domestic and foreign economies are expected to be similar leading to similar responses of current prices and nominal interest rates. Consequently, nominal variables are more synchronize across countries even when central banks only focus on domestic output and inflation.

However, we focus on the literature that measures global inflation as a common shock to inflation rates across countries, and not on the determinants of global inflation. Wang and Wen (2007) document that short term inflation dynamics is highly correlated across countries which is not fully explained by New-Keynesian sticky price model and sticky information model. Co-movements in inflation rates of 22 OECD countries over a sample period of 1961-2008 are measured by Ciccarelli and Mojon (2010). They used three alternate measures of global inflation (cross country averages, the aggregate OECD inflation and a measure based on static factor analysis) and compute the extent to which variance of national inflation rate can be explained by global inflation. The measure based on static factor analysis is estimated using a static factor model where a common factor to all countries inflation rate is obtained using a static principal component method. They show that 70 percent of the variations in national inflation rates can be explained by a single global factor. Their paper is followed by several studies attempting to explore international dimensions of inflation where they have estimated the co-movements in inflation rates across countries using dynamic factor models.

[19] see Wang and Wen (2007), for example.

Dynamic factor models have been used as a standard and popular econometric tool to measure the co-movements in macroeconomic variables and to forecast macroeconomic time series.[20] Several studies use dynamic factor models to measure the international co-movements of macroeconomic variables.[21] The presumption of dynamic factor model is that the observed co-movements in a large set of time series is due to small number of unobserved common dynamic factors. The observed co-movements that are not due to common factor are attributed to idiosyncratic shocks which are not correlated to common disturbances. Thus the model is used to identify the dynamics of time series attributable to some common factors and to idiosyncratic shocks.

Bagliano and Morana (2009) investigate the common factor in a set of macroeconomic variables including inflation for the United States, the United Kingdom, Japan, Canada and the Euro Area over a sample period, 1980-2005. They adopt a factor vector autoregressive framework derived from a dynamic factor model. They estimate a common factor as the first principal component and document that the fraction of variance in national inflation rates attributable to first principal component is 70 percent. This result is the same as reported by Ciccarelli and Mojon (2010) for a larger sample of countries and over a larger sample period.

Co-movements in inflation rates of 64 countries are measured by Neely and Rapach (2011) over a long sample period, 1951-2009 using a dynamic factor model (64 countries include advanced and developing countries). They decompose variance of inflation due to a world factor, seven regional factors and a country specific factors. They document that on average, 35 percent of the variability in annual inflation rates is explained by a global factor, 16 percent by a regional factor and 49 percent by country specific factors. To examine the relative importance of global, regional and country specific factors over time, they split the full sample periods into sub samples of 1951-1979 and 1980-2009. They find that on average, the relative importance of the factors in explaining the variance of national inflation rates is fairly stable. However, the global factor gains

[20] Early contributions to dynamic factor modelling are due to Forni and Reichlin (1998) who developed the frequency-domain approach of the model and Stock and Watson (2002) who developed the time-domain approach of the model and used the model to forecast inflation. For a survey on dynamic factor models, see Stock and Watson (2011).

[21] For example Kose et al. (2003), Kose et al. (2008) and Negro and Otrok (2008) used the model to measure co-movements in real macroeconomic variables, Bagliano and Morana (2009) measure the co-movements in a set of real and nominal(stock market returns, inflation rate, interest rates and monetary aggregates) macroeconomic variables. Stock and Watson (2007) used for inflation and Stock and Watson (2010) used for U.S. housing construction.

importance for some Latin American and Asian countries and the regional factor gains some importance for North American and the European countries.

Aggregate inflation may mask some of the underlying sectoral shifts. Thus it is interesting to quantify comovements in disaggregated inflation. To measure the co-movements in disaggregated inflation, Monacelli and Sala (2009) use the disaggregated price data in a sample of four industrial countries (i.e. the United States, France, Germany and the United Kingdom) over a sample period of 1991-2004. They find that on average 15 to 30 percent (depending on the type of data transformation applied, i.e., month-on-month as opposed to year-on-year) of the variance of inflation is explained by international common factor. They argue that their results are different from Ciccarelli and Mojon (2010) due the fact that aggregation of the sample matters in the estimation of the contribution of common factor in total variance of a panel. As their sample is highly disaggregated as compare to Ciccarelli and Mojon (2010), their results should be considered as a lower bound for the variance of consumer price inflation that is explained by the international factor.

The above cited studies, measuring the global inflation, estimate dynamic factor models with fixed parameters and assume constant variances. However, the data on inflation shows that inflation process has changed over time and volatility of inflation does not remain constant over time. It has been suggested by several studies that inflation process has significantly changed over time.[22] Mumtaz and Surico (2012) take into account the time varying dynamics of inflation process and measure the co-movements of inflation in a panel of 164 inflation indicators for the G7, Australia, New Zealand and Spain. They use a dynamic factor model with time varying coefficients and stochastic volatility. They find that an international factor tracks the level and persistence of national inflation rate reasonably well. However, they show that changes in relative importance of the common and country specific factor in explaining the variance of national inflation rates is not synchronized across countries. Moreover, they note that the contribution of world and national factors in explaining the variance of inflation has decreased in periods of inflation stability.

[22]Such as Cecchetti et al. (2007),Cogley and Sargent (2005) and Canova and Gambetti (2009).

To summarise, the empirical literature identifying the co-movements in inflation rates across countries is limited. However, the existing evidence is mixed. Ciccarelli and Mojon (2010) and Bagliano and Morana (2009) who measure the common factor by estimating first principal component report that the common factor is dominant in explaining the variance of national inflation. Whereas, other above cited studies show that though the global factor is important in explaining the variance in inflation rates yet the country specific factors play a dominant role.

2.4 Monetary Policy in Global Environment

The strong synchronization on inflation rates and to a lower extent correlation of output gap across countries have important implications for monetary policy making. Though there exists a controversy regarding the extent to which the observed co-movements are attributable to globalization, practice of common monetary policy and to common commodity price shocks, yet it is generally accepted that the global forces are important. Considering the importance of global forces, monetary policy authorities should take them into account along with domestic developments, as noted by Ciccarelli and Mojon (2010), "The main risk of ignoring international developments is to overrate the importance of domestic developments."

The importance of considering international developments is highlighted by a number of Central Bankers in their speeches. For instance, Smaghi (2011) notes that increasing importance of global inflation can not be ignored any longer while forecasting inflationary pressures. Bullard (2012) also stresses the importance of global output gap in case of the United States. He notes that the U.S. inflation has increased recently while typical estimates show that it should have remained low during 2011 as suggested by measure of output gap. He suggests that it may be because the Federal Reserve is not giving appropriate weights to global conditions. The U.S. output gap is not relevant for U.S. inflation rather it is the global output gap that matters.[23] Moreover, he argues that the global inflation might be responsible for increase in the U.S. price level. He

[23]the other explanation, according to him, could be that output gap is not as wide as commonly supposed.

notes that monetary authorities can only ignore foreign output gap when inflation is defined as “domestic(producer) price inflation” and exchange rates are perfectly flexible, the conditions which are not often met in reality.

Monetary policy rules for open economy are developed by several studies. Some studies develop variants of the original Taylor (1993) Rule by incorporating the foreign variables while some alternative open economy rules are also developed. An important alternative open economy policy rule to the Taylor Rule, is developed by Ball (1999b). He extends the Svensson (1997) closed economy model to an open economy setting and assess how the optimal policies change in open economies. He derives optimal instrument rule from three open economy equations. A dynamic open economy IS equation, where output depends on lags of itself, the real interest rate and the real exchange rate; the open economy Phillips Curve where the change in inflation depends on lagged inflation and lagged changes in exchange rate (which affects inflation through import prices) and the equation establishing the relationship between interest rate and exchange rate that captures the behaviour of asset market. His optimal instrument rule differs from the Taylor Rule in the closed economy in two ways. First, the policy instrument is a weighted sum of the interest rate and the exchange rate (a monetary condition Index). Secondly, on the right hand side of the policy rule, inflation is replaced by long run inflation which is a measure of inflation adjusted for the temporary effects of exchange rate fluctuations. Hence, the Ball’s (1999b) open economy policy rule is a Monetary condition Index (MCI)) based.

A Monetary Condition Index is a weighted average of the domestic interest rate and the (log) exchange rate which are often used to measure the stance of the monetary policy in an open economy. However, MCIs are theoretically and empirically criticized in the literature (see for example Batini and Turnbull (2000) and Batini et al. (2003)). One constructional flaw of MCI based rule is that it makes difficult the identification of exchange rate shock because it focuses on aggregated exchange rate and interest rate instead of focusing movements in exchange rate and interest rate in isolation. Thus the performance of the MCI based rules depends on the nature of the shocks. It may perform poorly in the face of the shocks that affect the exchange rate but do not ask for a compensating change in interest rates and thus may not be used as a guidance policy rule (Batini et al. (2003)).

Open economy rules are analysed by Batini et al. (2003) who modify Ball's closed and open economy rules. They estimated a policy rule for a small open economy like the United Kingdom using a two sector open economy dynamic stochastic general equilibrium model. They evaluated and compared the performance of simple monetary policy rule i.e. Taylor Rule, inflation-forecast based rule, a MCI based rule, Ball (1999b) and a family of alternative 'open economy' rules in their model setting. To account for the openness of the economies, they consider four different rules, three of which are variants of Ball (1999b) open economies rules.[24] First they augment the Ball (1999b) rule with a balance of trade term. Second, they replace the aggregate output with output gaps in two sectors (exports and non-traded). In the third variant they use the Ball (1999b) rule with a restriction on the contemporaneous and lagged exchange rate terms so that their coefficients are equal and opposite implying that policy makers respond to the changes in real exchange rate rather than levels. The fourth rule is a modification of inflation forecast based rule of Batini and Haldane (1999) by adding lagged and current real exchange rate terms. They conclude that an inflation forecast based rule (a rule that reacts to deviations of expected inflation from target) performs best as it appears quite robust to different shocks and is associated with a lower than average variability of inflation when compared to alternative rules.

Policy rules in an open economy perspective are also examined by Svensson (2003). He investigates open economy issues in a forward-looking framework which includes foreign variables such as foreign exchange risk premium, real exchange rate and foreign interest rate (modelled as determined by a Taylor-type rule). He derives an optimal rule for the domestic interest rate which includes one or most of these foreign variables. Kirsanova et al. (2006) show that in a model with Uncovered Interest rate Parity (UIP) shocks, reaction function can be written as including the real exchange rate gap term and a terms of trade gap. However, they show that Central Banks should not directly respond to the changes in nominal exchange rates as the response to consumer price

[24]They re-arrange the Ball (1999b)'s rule so that it resembles Taylor rule augmented with contemporaneous and lagged real exchange rate terms.

inflation can be thought as a combination of response to changes in nominal exchange rate and to output price inflation.

To examine the stance of monetary policy in international perspective, variants of the Taylor Rule by incorporating foreign variables are estimated by several studies. The original Taylor (1993) Rule was developed for a closed economy which is considered a useful yardstick to assess the stance of monetary policy. The Taylor rule, a simple mechanical monetary policy rule, implies that Central Banks aim at stabilising inflation around a targeted level and output around its potential. The positive deviations of inflation from its target and of output from potential are responded by tightening the monetary policy and negative deviations are associated with loosening the monetary policy. However, the closed-economy Taylor Rule may not be appropriate for open economies.

Accordingly, the Taylor Rule augmented with international variables are estimated by several studies to examine the role of foreign developments in domestic monetary policy. For instance Adam et al. (2005) estimate the Taylor Rule for the U.K. augmented with the U.S. and German interest rate for pre Exchange Rate Mechanism (1985-1990) era, post Exchange Rate Mechanism era (1992-1997) and the era of Monetary Policy committee (1997-2003). They conclude that the U.S. and German interest rate can be clearly included in the U.K. monetary policy reaction function and domestic variables have no contribution in the pre-ERM period and only a weak contribution at best in the post ERM period. Most influential empirical work on Taylor Rule in international context is due to Clarida et al. (1998). They estimate the forward-looking Taylor Rule for the U.S. Germany, Japan, France, Italy and U.K. They provide evidence of foreign influences on France, Italy, Japan and the U.K monetary policies.

However, some authors argue that Central Banks should consider the effects of exchange rate fluctuation on inflation and output gap rather than an independent role of exchange rate when implementing monetary policy. For instance, Clarida et al. (2001) conclude that optimal monetary policy should have the same form for an open economy as for a closed economy and monetary policy should not respond to foreign interest rate or exchange rate. Taylor (2008) argues that moving interest rate in response to inflation or expected inflation already includes an indirect response to exchange rate movement as depreciation of the exchange rate increases inflation. He stresses that reacting directly to exchange rate will cause "herky-jerky" movements in the interest rate which is harmful for the economy. Similar is the argument of Monetary Policy Committee, it would not be sensible for policy to react to high frequency movements in the exchange rate, as it could lead to a volatile path of interest rates from month to month, and might make it more difficult for others to understand the motives for interest rate changes. Similar discussion and conclusion is given by Mishkin (1995).

However, Edwards (2006) argue that Central Banks do take exchange rate behaviour into account while conducting monetary policy although they do not openly recognize it. He investigates the role of exchange rate in Inflation Targeting countries and find that Inflation Targeting countries with a history of high and unstable inflation tend to take into account the fluctuation in nominal exchange rate when undertaking monetary policy.

A number of specification and estimation issues are raised in literature on the Taylor Rule estimations for closed or open economies. Inference from the estimates of the Taylor Rule is sensitive to these issues. The first issue concerns including the interest rate smoothing term in the Taylor Rule. The original Taylor Rule does not include the lagged interest rate term. However, most of the empirical research later concludes that a lagged dependant variable should be included in the Taylor Rule regression to allow for interest rate persistence or smoothing behaviour on the part of Central Bank.[25]

The second issue is regarding the weights embedded in inflation and output gap. In the original Taylor Rule a weight of 0.5 is specified on output gap while in theoretical research, Ball (1999a) and Rudebusch and Sevensson (1999) argue for a higher than 0.5 weight on output gap. On the other hand Rotemberg and Woodford (1999) argue for a smaller response to output gap. However, empirically it is found that the Federal reserve has reacted differently to output gap over time.[26] The issue, whether the policy

[25]See for example, Sack (1998, 2000), Sack and Wieland (2000),Collins and Siklos (2004), English et al. (2003), Goodhart (1999) and Clarida et al. (1998).

[26]For example for post 1979 period, Clarida et al. (2000) report a coefficient of 0.93, Kozicki (1999) reports different

reaction function satisfies the Taylor principle (weight on inflation is greater than one) is extensively discussed by Clarida et al. (1998) and Taylor (2008). Clarida et al. (1998, 2000), Adam et al. (2005) and Hayo and Hofmann (2006) report weights well above unity on inflation for the U.S., the U.K. and the ECB (European Central Bank) respectively. However, Clarida et al. (2000) produce weight of less than one (0.83) for Pre-Volker period in the U.S. suggesting that estimates are sensitive to the estimation sample period. For the open economy Taylor Rule, Clarida et al. (1998) found that when they added German interest rate to their baseline reaction function for France, Italy and the U.K. the weight on inflation fell from around one to 0.5. Ball (1999b) found that the coefficient on inflation in his open economy model should not differ substantially from that in his closed economy model(Ball (1999a)).

Third, different measures of output gap and inflation are used while estimating the Taylor Rule. Kozicki (1999) used different measures of output gap and inflation to estimate the Taylor Rule and showed that results are not robust across different measures. Fourth issue concerns the timing of economic variables on which interest rate setting depends, i.e. use of current versus real time data. The policy makers take decisions on the basis of information that is available to them at that time while output data is revised at later dates. Most of the empirical work is based on revised data. In recent literature, the Taylor Rule is estimated using real time data.[27] Molodtsove et al. (2008) estimated the Taylor Rule for the U.S. and Germany and find that there is a small difference between the estimates of the Taylor Rule obtained from revised and real time data for the U.S. However, the German policy rule satisfies the Taylor principle only when estimated using real time data.

Despite the issues described above which are not exhaustive, the Taylor Rule is generally accepted as a simple and useful guideline for monetary policy.

To summarise, we reviewed the theoretical and empirical literature on inflation-globalization nexus and the implications of globalization for monetary policy. The impact of globalization on domestic inflation is examined through several channels such as trade effect

weights with different specifications of Taylor Rule for 1983-1997.

[27]See for example Adema (2004), Gerdesmeier and Roffia (2004) and Molodtsove et al. (2008).

due to import prices, through competition and labour markets, sensitivity of domestic prices to domestic and foreign out put gap. The empirical evidence on the effects of globalization on domestic through these channels is not conclusive. Another newly developed strand of literature attempts to measure the global component in national inflation rates across countries and identify that a significant amount of variance in aggregate and disaggregate inflation is due to a common global factor. However, the evidence is not conclusive on whether the global forces are dominant in driving the national inflation series or the country specific factors play more important role. Another limitation of the literature on globalization of inflation is that most of the studies assume constant variance of inflation and do not take into account the time varying volatility.

For the implications of globalization on monetary policy, several studies develop open economy policy rules. The Taylor Rule is modified and estimated to take into account the foreign effects on domestic monetary policy. The literature provides empirical evidence that the monetary policy open economies respond to international factors.

We will contribute to the literature on globalization and inflation in a number of directions in Chapter 3 and 4. Chapter 5 contributes to the literature on the implications of globalization for monetary policy.

Table 2.1: Representative studies estimating co-movements in inflation rates across countries with Dynamic Factor Modelling

Authors	**Sample Period**	**sample countries**	**Data**	**World Factor**	**Regional Factor**	**Stochastic Volatility**
Monacelli and Sala(2009)	1991-2004	4 OECD Countries	Disaggregate Inflation (948 CPI Products)	Yes	No	No
Ciccarelli and Mojon(2010)	1961-2008	22 OECD Countries	Aggregate Inflation (CPI inflation)	yes	No	No
Neely and Rapach(2011)	1951-2009	64 Countries	Aggregate Inflation (CPI inflation)	Yes	yes	No
Mumtaz and Surico(2012)	1961-2004	13 Industrial Countries	Disaggregate Inflation (164 indicators)	Yes	No	Yes

Notes: The table shows the representative studies estimating co-movements in inflation rates across countries with Dynamic Factor Modelling approach. We estimte dynamic factor modelling with stochastic volatility and decompose inflation into a global factor, regional factors and idiosyncratic component.

Chapter 3

Aggregate Inflation and Globalization

3.1 Introduction

Aggregate inflation rates have been observed to be low and increasingly stable across industrial countries since the late 1980s. Indeed, many industrial countries over this period have experienced approximately similar inflation rates and the co-movement of inflation has been substantially high. The common macroeconomic shocks, and similar response to these shocks by central banks, are often attributed to produce the co-movements in inflation rates. However, Wang and Wen (2007) argue that common oil price shocks and monetary policy may not be the whole story behind international synchronization of inflation rates. We therefore, are interested in understanding the origin and nature of this co-movement in inflation rates across OECD countries. This has important policy implications because understanding the source and nature of international fluctuations in inflation leads to effective domestic policy making and reduces the risk of over reacting the domestic factors and ignoring the global ones.

Dynamic factor models have become standard and popular econometric tool to measure the extent and nature of co-movements in macroeconomic time series by decomposing their variability into a global and idiosyncratic component.[1] To identify the co-movements in inflation rates across countries, a static factor model is used by Ciccarelli and Mojon (2010). They conclude that inflation in OECD countries is a global phenomenon as almost 70 percent of the variance in inflation is attributable to a common factor. Bagliano and Morana (2009) estimate common factor in inflation rates of a number of developed economies using dynamic factor model and produce similar results as of Ciccarelli and Mojon (2010). Mumtaz and Surico (2012) and Neely and Rapach (2011) estimate dynamic factor models to estimate the co-movements in inflation inflation. They decompose the inflation series of large number of countries into a global, regional and national factors with constant variance. Mumtaz and Surico (2012) decompose disaggregated inflation series of a sample of industrial countries into global and national factors with time varying stochastic volatility, without documenting the importance of global and national factors on average. They show that the role of world and national factors has decreased over time in explaining the variance of inflation.

We argue that the dynamic factor models with the assumption of constant nature of co-movements of inflation and constant variance of inflation may not well explain the dynamics of inflation process given that the volatility of inflation has declined overall. Cogley and Sargent (2002), for example, document that the U.S. inflation dynamics have changed in post war period. Therefore, we go beyond a simple constant variance model of inflation and apply dynamic factor model with stochastic volatility to allow for the time variation in the volatility of factor and idiosyncratic disturbance term. To characterize the common and idiosyncratic aspect of changes in country-level volatility, we use the dynamic factor model introduced by Geweke (1977). This is modified for stochastic volatility in the factors and idiosyncratic disturbances by Stock and Watson (2010) and is referred as the Dynamic Factor Model with Stochastic Volatility (DFM-SV).

Moreover, the regional factors may have become important in driving inflation process especially in regions that experience increased intra-regional trade and economic

[1]Kose et al. (2003), Kose et al. (2008) and Negro and Otrok (2008) use this approach to understand the dynamics of business cycles, Stock and Watson (2010) for U.S. housing construction, Stock and Watson (2007) for U.S inflation and Ciccarelli and Mojon (2010),Mumtaz and Surico (2012),Monacelli and Sala (2009), and Neely and Rapach (2011) for inflation in OECD and a number of other countries.

globalization. Intra- regional economic linkages has become strong in countries who have been taking regional integration initiatives such as regional trade agreements and common currency areas. For instance, formation of the European Monetary system and the Treaty of Maastricht in 1992 enhanced the economic integration among the member countries. Hence, it is interesting to estimate the regional factors as driving force of variances in national inflation rates.

We contribute to the literature by decomposing inflation rates of 22 OECD countries into a global component, a regional component and country specific component using dynamic factor model with stochastic volatility.[2] As choice of regional composition is subjective, we identify regions endogenously and exogenously. Regions are determined endogenously by letting the data decide the regional composition of countries by using K-means clustering and three exogenously identified regional compositions are also used. Furthermore, we examine whether the high co-movements in inflation rates across countries are due to increased globalization.

Thus our study differs from previous studies in a number of ways. First, this is the first study that decompose inflation into a global, regional and country specific factors with time varying stochastic volatility. Secondly, we use different endogenously and exogenously determined compositions of regions and attempt to identify the effects of regional integration enhanced by creation of the EMS and the Euro Area on regional factors. Thirdly, we investigate empirical relationship between the estimated international factors and economic globalization.

In the DFM-SV model, inflation is a function of a single global factor, regional factors, and a country specific component. For the regional factors, we estimate composition of the regions exogenously and endogenously. We applied K-means clustering analysis to estimate regions endogenously after extracting the global component from the inflation series. We estimate our dynamic factor model in two steps. First, with constant disturbance variances over the two split sub samples (1961-1982 and 1983-2008) and then estimate DFM-SV model. We split the sample at 1983 as it coincide with the

[2]Though regional factors are estimated by Neely and Rapach (2011) yet they do not introduce stochastic volatility and Mumtaz and Surico (2012) estimate the dynamic factor model with stochastic volatility without regional factors and use a small sample of countries.

U.S. experience of Volckers disinflation, profound monetary policy changes in many countries in our sample and a subsequent era of overall low macro economic volatility known as Great Moderation. In addition, a structural break at mid 1980s is strongly supported in literature.[3] The DFM-SV model verifies the results produced by split sample analysis and explains the changes in dynamics of inflation over time that is masked by split sample analysis.

We find that the largest variance of inflation can be mostly explained by the country specific component followed by the global and the regional factors respectively. These results generally agree with Neely and Rapach (2011) and Mumtaz and Surico (2012). The contribution of the global factor in explaining the volatility of inflation has fluctuated yet the overall importance of global factor has increased overtime while the importance of the country specific component has decreased in explaining the variance of inflation over time and role of average regional factor has been small and has remained fairly unchanged over time. However, the split sample analysis shows that the role of regional factor is substantially increased for the countries which have strong intra-regional linkages. We find that since 1999, role of global and regional factors (added together) dominates the country specific factor in explaining the variance of inflation. Finally, the volatility of the idiosyncratic disturbance term has declined substantially over time.

We test the empirical relationship between the estimated international factor(global and regional) and globalization. For measure of globalization, we used the measure of economic globalization based on KOF index of globalization 2011 (Dreher et al. (2008)). We find a positive and significant relationship between international factor and economic globalization since late 1990s, supporting the view that inflation rates are synchronized internationally due to increased globalization.

The rest of the chapter is set out as follows: Section 3.2 reviews related literature; Section 3.3 explains our data and provides summary statistics; Section 3.4 outlines the econometric methodology; Section 3.5 discusses the empirical results; Section 3.6 provides evidence of relationship between the contribution of international factors in

[3] See for example, Gadea and Mayoral (2006) and Courvoisier and Mojon (2005) and Ciccarelli and Mojon (2010).

variance of national inflation rates and economic globalization; Section 3.7 concludes and summarises the main results.

3.2 Review of Literature

There is a growing volume of literature assessing the impact of globalization on inflation. Trade openness, international competition in factor markets and financial integration are among the main channels through which globalization is believed to be affecting the inflation process. Three major implications of relationship between globalization and inflation are assessed in literature. The first widely tested implication is that the role of foreign capacity utilisation or foreign output gap as a determinant of domestic inflation has been increased in the global economy. The hypothesis is tested in the literature by estimating a standard Phillips Curve augmented with some global explanatory variables for individual developed countries[4] or for a panel of countries.[5]

The empirical evidence on role of the foreign output gap in the determination of domestic inflation is overall mixed. Tootell (1998) find that the foreign output gap does not effect the United States inflation, while Milani (2009) verify the results of Gamber and Hung (2001) and Wynne and Kersting (2007) and find that global slack has become an important determinant of domestic inflation after 1985. The broadest evidence in favour of role of foreign output gap in the determination of domestic inflation of 16 OECD countries is provided by Borio and Filardo (2007), which is challenged by Ihrig et al. (2007) who show that the results of Borio and Filardo (2007) are not robust to alternate measures of foreign output gap.[6] The evidence against the role of the foreign output gap in the determination of domestic inflation is also provides by Hooper et al. (2006), Ball (2006), Koske et al. (2010) and Calza (2009).

[4]Tootell (1998), Gamber and Hung (2001),Wynne and Kersting (2007) estimated standard Phillips Curve for United States augmented with trade weighted foreign output gap of major U.S. trading partners.

[5] For example see Hooper et al. (2006), Borio and Filardo (2007), Ihrig et al. (2007), and Calza (2009).

[6]Borio and Filardo (2007) measured five different versions of global output gap with the weights given by exports plus imports, imports, exchange rate, a mix of exchange rate and trade and global GDP. While, Ihrig et al. (2007) calculate the foreign output gap as a time varying weighted average of output gaps of a fixed group of 35 trading partners, with the weights given by annual bilateral imports from and exports to other countries along with measure of competition with third party markets.

The second important implication of the relationship between globalisation and inflation is that sensitivity of domestic inflation to domestic output gap is decreasing with increased globalization which implies that the Phillips Curve has become flatter. Evidence on the flattening of Phillips Curve is abundant in industrial economies.[7] However, there is unsettled debate in literature that it is due to improved monetary policy framework or increased globalization.[8] The impact of globalisation on inflation is further analysed by using a Phillips Curve augmented with an interaction term between domestic output gap and trade openness.[9] IMF (2006) finds that the sensitivity of inflation to domestic output has decreased since the 1980s and the key factor behind the reduced sensitivity of prices to output is found to be trade openness. Similar findings are reported by Koske et al. (2010), Borio and Filardo (2007) and Dexter et al. (2005).

In contrast to these finding, Ball (2006) argues that even with greater international competition a firm's marginal cost depends on the firm's own level of output rather than global ones. Therefore, globalisation has neither reduced the long run inflation nor it has affected the structure of inflation process. His empirical results show that the effect is of marginal statistical significance which is verified by Ihrig et al. (2007). The effect of globalisation on the slope of Phillips Curve is investigated from a theoretical perspective in a two-country new Keynesian model by Woodford (2010). He concludes that the slope of Phillips Curve is not reduced by global integration and global slack has no role in the determination of supply side inflationary pressure in an open economy model.

The third important channel through which globalization may have an effect on inflation is imports from low cost countries. Therefore, the impact of globalization on inflation can be investigated by estimating the direct impact of imports from lower cost economies. Koske et al. (2010) use an accounting framework to estimate the direct impact of import prices from non-OECD on OECD import price inflation. They

[7] See IMF (2006), Koske et al. (2010), Roberts (2006), Williams (2006) and Borio and Filardo (2007).

[8] For example Ball (2006), and Mishkin (2009) argue that low and stable inflation in the U.S. since 1990s is the result of better policy and well-anchored inflation expectations and globalization has had a little role in changing the determinants of inflation and Temple (2002) and Wynne and Kersting (2007) find no significant impact of openness on sacrifice ratios or on the slope of Phillips Curve.

[9] Trade openness is measured as a share of non oil trade in GDP by IMF (2006) while, Ball (2006) and Ihrig et al. (2007) measure it by the share of trade (exports plus imports) in total GDP.

find that the contribution of import prices in driving up the consumer prices has become increasingly important since the mid 1990s. Gamber and Hung (2001) conduct the analysis for the United States over a period of 1987-92 and show that domestic prices in particular sectoral categories were sensitive to prices of imports in the same categories and sensitivity was greater in the sectors which were faced with greater import penetration. However, Kamin et al. (2006), IMF (2006), Ihrig et al. (2007) and Guilloux and Kharroubi (2008) report a small impact of import prices on inflation.

The review of the literature analysing the globalization of inflation through the Phillips Curve estimation shows that the evidence is not conclusive. Another novel and interesting approach has emerged recently to assess the global dimension of inflation. Global inflation is measured by static and the dynamic Factor models.[10] This model is used to study the co-movements of macro economic variables by decomposing the variable into a common and idiosyncratic component.[11] Monacelli and Sala (2009), Mumtaz and Surico (2012) and Neely and Rapach (2011) use this approach to examine the inflation dynamics for different set of countries.

Ciccarelli and Mojon (2010) compute the share of the variance of national inflation rates explained by three different measures of global inflation (a cross country average, the aggregate OECD inflation and a measure based on static factor analysis). They show that the inflation rates of 22 OECD countries have a common factor that alone accounts for almost 70 percent of their variance and if the inflation series are detrended to remove the common trends, the share of national inflation variance explained by common factor is around 37 percent. They further decompose the forecast error variance into common shock, national shock and spillovers of domestic shock from other countries and find that global inflation occurs as a result of common shocks and not from countries spillovers.

Co-movements in inflation rates of 64 countries are measured by Neely and Rapach (2011) over a long sample period, 1951-2009 using dynamic factor model. They decompose the variance of inflation due to a world factor, seven regional factors and

[10]For early contribution to the dynamic factor model, see Forni and Reichlin (1998) and Stock and Watson (2002).

[11]For example, Kose et al. (2003, 2008) and Negro and Otrok (2008) used the model for real macroeconomic variables. Stock and Watson (2010, 2007) for Inflation and U.S. Housing Construction.

a country specific factors. They document that on average, 35 percent variability in annual inflation rates is explained by a global factor, 16 percent by a regional factor and 49 percent by country specific factors. To examine the relative importance of global, regional and country specific factors over time, they split the full sample periods into sub samples of 1951-1979 and 1980-2009. They find that on average, the relative importance of the factors in explaining the variance of national inflation rates is fairly stable. However, the global factor gains importance for some Latin American and Asian countries and the regional factor gains some importance for North American and European countries.

To investigate the co-movements in disaggregated inflation, Monacelli and Sala (2009) use the disaggregated price data in a sample of four industrial countries (the United States, France, Germany and the United Kingdom) over a sample period of 1991-2004. They find that on average 15 to 30 percent (depending on the type of data transformation applied, i.e., month-on-month as opposed to year-on-year) of the variance of inflation is explained by an international common factor. They argue that their results are different from Ciccarelli and Mojon (2010) due the fact that aggregation of the sample matters in the estimation of the contribution of common factor in total variance of a panel. As their sample is highly disaggregated as compare to Ciccarelli and Mojon (2010), their results should be considered as a lower bound for the variance of consumer price inflation that is explained by the international factor.

The above cited studies, measuring the global inflation, estimate dynamic factor models with fixed parameters and assume constant variances. However, the data on inflation shows that inflation process has changed and volatility of inflation does not remain constant over time. It has been suggested by several studies that inflation process has significantly changed over time.[12] A study by Mumtaz and Surico (2012) takes into account the time varying dynamics of inflation process and measures the co-movements of inflation in a panel of 164 inflation indicators for the G7, Australia, New Zealand and Spain. They use a dynamic factor model with time varying coefficients and stochastic volatility. They find that an international factor tracks the level and persistence of

[12] Such as Cecchetti et al. (2007),Cogley and Sargent (2005) and Canova and Gambetti (2009).

national inflation rate reasonably well. However, they show that the changes in relative importance of the common and country specific factor in explaining the variance of national inflation rates is not synchronized across countries. Moreover, they note that the contribution of world and national factors in explaining the variance of inflation has decreased in periods of inflation stability.

To summarise, the empirical literature identifying the co-movements in inflation rates across countries is limited. However, the existing evidence shows mixed results. Ciccarelli and Mojon (2010) and Bagliano and Morana (2009) who measure the common factor by estimating first principal component report that the common factor is dominant in explaining the variance of national inflation. whereas, other above cited studies show that though the global factor is important in explaining the variance in inflation rates yet the country specific factors play a dominant role.

3.3 Data and Summary Statistics

3.3.1 The Data

We use quarterly values of CPI indices (2000 =100) from OECD Main Economic Indicators database for 22 OECD countries for the period 1961-2008. The countries in our sample include: Austria, Australia, Belgium, Canada, France, Finland, Germany, Greece, Italy, Japan, Korea, Luxembourg, New Zealand, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, South Africa, the United Kingdom, and the United States. We follow Ciccarelli and Mojon (2010) and compute the quarterly year on year inflation rate to remove the seasonal pattern.

$$\pi_{it} = ln(\frac{P_{it}}{P_{it-4}}) \cdot 100 \tag{3.1}$$

where, P_{it} is quarterly CPI.

3.3.2 Summary Statistics and Plots

The inflation rate for G7 countries are plotted in Figure 3.1 where two features are noteworthy. First, we observe three different phases of inflation over our sample. During the 1960s inflation is moderate while from the early 1970s to early 1980s, we observe very high and volatile inflation which may be associated with the oil price shocks and the subsequent decline in OECD productivity. From early 1990s onwards, low and stable inflation is experienced by most of the industrial economies which may be attributed to various factors such as increased globalization, well anchored inflation expectations, prudent monetary policy and simultaneous adoption of Inflation Targeting as a new monetary policy framework by a number of OECD countries. The second striking feature in Figure 3.1 is that inflation rates of almost all the countries appear to move together and seems to have a significant common component throughout the entire sample period. Thirdly, the volatility is not constant and has decreased substantially over time.

Inflation rate changes for 22 countries are plotted in Figure 3.2 (dotted lines) whereas solid lines are the median, 25 percent and 75 percent percentiles of inflation rate across countries. We can observe the similar pattern depicted by median inflation rate as we noticed in the plot of inflation rates in Figure 3.1. Inflation in all the countries is low, stable and less volatile in the second part of the sample and move together throughout the sample.

Summary statistics for inflation rates of 22 OECD countries are presented in Table 3.1. The average inflation rate across the sample ranges from 4 percent to 9 percent. In the second and the third column of Table 3.1, standard deviations of inflation rate for the period 1961-1982 and 1983-2008 are reported. It is evident that inflation volatility is substantially decreased in second sample in most of the countries. We split the sample around 1982 which coincide with the beginning of the Great Moderation and a number of economists provide evidence of a structural break in the mid 1980s for most of the countries in our sample. For most of the OECD countries Courvoisier and Mojon (2005) identify the structural break around the mid 1980s which coincide with significant monetary changes in these countries.

We construct the 95 percent confidence interval by inverting the ADF t_μ statistic and compute the DF-GLS statistics proposed by Elliott et al. (1996) to examine the stationarity properties of inflation series and Ng and Perron (2001) MZa and MZt test statistics that are modified versions of Phillips (1987) and Phillips and Perron (1988) Za and Zt tests, all computed using maximum four lags in the quarterly data. The lag selection criterion used for DF-GLS and Ng and Perron statistics is the modified AIC proposed by Ng and Perron (2001). The confidence intervals reported in fourth and fifth column indicate that the largest AR root is near one and all confidence intervals contain a unit root. The DF-GLS and Ng and Perron statistics rejects the unit root in five and four countries inflation series respectively. Therefore, we suggest modelling the series as containing a unit root.[13]

3.3.3 Rolling Standard Deviations and Correlations

Inflation volatility has not been constant over time. It can be observed in Figure 3.2 that the inflation volatility has declined considerably since the late 1980s. The figure also shows substantial co-movement of inflation rate across countries. Substantial correlation in inflation rates across countries is verified by the cross country correlation matrix presented in Table 3.2. The cross country correlation in the inflation series of all countries in our sample is positive. The maximum correlation is observed between Luxembourg and Belgium (94 percent) followed by 92 percent between Italy and France. Minimum correlation is between South Africa and Netherlands and between South Africa and Korea (i.e. 2 percent). Inflation rates in the United Kingdom are highly correlated with inflation in Finland and France whereas inflation rates in the United States are highly correlated with Canada. The sample average is 0.64 and standard deviation is 0.17. Hence, it provides a preliminary and informal evidence for significant correlation.

[13]However, the debate on the presence of unit root in inflation series is unsettled empirically. Nelson and Ploseer (1982) point out that macroeconomic series often contain unit roots. Barsky (1987) and Brunner and Hess (1993) do not reject the unit root in OECD countries, OReilly and Whelan (2005) for the Euro Area, Crowder and Hoffman (1996) and Gadzinski and Orlandi (2004) and Stock and Watson (2007) for the US and Byrne et al. (2010) for UK aggregate inflation.

Rolling standard deviations of inflation rate for 22 countries are computed using a centred 21-quarter window and are plotted in Figure 3.3. Solid lines are the median, 25 percent and 75 percent percentiles. The median standard deviation clearly depicts a remarkable decline in inflation volatility since late 1980s.

As we observe in Figure 3.2 that inflation rate across the countries move together and the cross country correlation matrix presented in Table 3.2 shows that the correlation of inflation across countries in our sample is positive and high for most of them. However, we are interested in measuring the time varying co-movement of inflation across all countries. Therefore, we compute the spatial correlation among 22 countries inflation over a rolling window to allow for time variation (see Stock and Watson (2010)). We use a measure based on Moran's I Statistics (Moran (1950)), applied to a centred 21-quarter rolling window to summarize the co-movements.

Let $X_i, (i = 1, ..., N)$, is a variable of interest then Moran's I is

$$I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(X_i - X)(X_j - X)}{\sum_{i=1}^{N}(X_i - \bar{X})^2} \cdot \frac{N}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}} \tag{3.2}$$

where w_{ij} is a matrix of spatial weights. Here, we are interested in the co-movement over time across all countries (so $w_{ij} = 1$ for $i \neq j$) as measured by the rolling cross-correlation in inflation rates. Accordingly, Moran's I, modified in our application is

$$\tilde{I}_t = \frac{\sum_{i=1}^{N}\sum_{j=1}^{i-1} cov(\Delta\pi_{it}, \Delta\pi_{jt})}{\sum_{i=1}^{N} var(\Delta\pi_{it})} \cdot \frac{N}{N(N-1)/2} \tag{3.3}$$

where, $cov(\Delta\pi_{it}, \Delta\pi_{jt}) = \frac{1}{21}\sum_{s=t-10}^{t+10}(\Delta\pi_{is} - \Delta\bar{\pi}_{it})(\Delta\pi_{js} - \Delta\bar{\pi}_{jt})$,
$var(\Delta\pi_{it}) = \frac{1}{21}\sum_{s=t-10}^{t+10}(\Delta\pi_{is} - \Delta\bar{\pi}_{it})^2$, $\Delta\bar{\pi}_{it} = \frac{1}{21}\sum_{s=t-10}^{t+10}\Delta\pi_{is}$ and $N = 22$

The time series $\tilde{I}_t$ is plotted in Figure 3.4 . We can observe that the spatial correlation is high in early-mid 1970, early 1980s, and early 1990s and is increasing sharply since late 1990s afterwards. The three peaks in spatial correlation coincide with the time periods which are identified as the break dates in the mean inflation of OECD countries by Courvoisier and Mojon (2005) over a period of 1960 to 2003.

The high spatial correlation in 1970s coincides with the oil price shocks of 1973 and 1979 that had its world wide effects. The second peak of spatial correlation in the early eighties is associated with the U.S. and the European disinflation (based on the European Monetary System). It is worth emphasizing that there has been a sharp increase in international co-movements of inflation across OECD countries since the late 1990s. The co-movements of inflation rates across countries are attributed to a variety of macroeconomic shocks, paradigm changes in monetary economics, economic, political and peer pressure of central banks to respond similarly to shocks and increased globalisation (Ciccarelli and Mojon 2010). However, Wang and Wen (2007) attempt to investigate the sources of international synchronization in inflation rates of G7 countries and argue that the oil price shocks and coordinated monetary policy among the developed countries are not the whole story behind the international synchronization of inflation suggesting that increased globalization may be one of the responsible factors for co-movements in inflation across the globe.

3.4 Econometric Methodology

3.4.1 The Dynamic Factor Model with Stochastic Volatility

In this section we present the dynamic factor model with stochastic volatility of Stock and Watson (2010). The aim of model is to capture a global component, a regional component, and an idiosyncratic component from the inflation rate series of OECD countries. Specifically inflation is modelled as the following dynamic factor model.

$$\pi_{it} = \lambda_i F_t + \sum_{j=1}^{N_R} \gamma_{ij} R_{jt} + e_{it} \tag{3.4}$$

where, π_{it} is the demeaned inflation rates and the global factor F_t and the N_R regional factors R_{jt} follows random walks and the idiosyncratic disturbance e_{it} follows an AR(1) process

$$F_t = F_{t-1} + \eta_t \tag{3.5}$$

$$R_{jt} = R_{jt-1} + \upsilon_{jt} \tag{3.6}$$

$$e_{it} = \rho_i e_{it-1} + \varepsilon_{it} \tag{3.7}$$

The disturbances η_t, υ_{jt} and ε_{it} are independently distributed and the factor disturbances have a stochastic volatility:

$$\eta_t = \sigma_{\eta,t}\zeta_{\eta,t} \tag{3.8}$$

$$\upsilon_{jt} = \sigma_{\upsilon,t}\zeta_{\upsilon,t} \tag{3.9}$$

$$\varepsilon_{it} = \sigma_{\varepsilon,t}\zeta_{\varepsilon,t} \tag{3.10}$$

$$ln\sigma^2_{\eta,t} = ln\sigma^2_{\eta,t-1} + \nu_{\eta,t} \tag{3.11}$$

$$ln\sigma^2_{\upsilon_j,t} = ln\sigma^2_{\upsilon_j,t-1} + \nu_{\upsilon_j,t} \tag{3.12}$$

$$ln\sigma^2_{\varepsilon_i,t} = ln\sigma^2_{\varepsilon_i,t-1} + \nu_{\varepsilon_i,t} \tag{3.13}$$

where $\zeta_t = (\zeta_{\eta,t}, \zeta_{\upsilon 1,t}, ...\zeta_{\upsilon_{N_R},t}, \zeta_{\varepsilon 1,t}, ...\zeta_{\varepsilon N,t})'$ is $i.i.d.N(0, I_{1+N_R+N})$, $\nu_t = (\nu_{\eta,t}, \nu_{\upsilon 1,t}$ $, ...\nu_{\upsilon_{N_R},t}, \nu_{\varepsilon 1,t}, ...\nu_{\varepsilon N,t})'$ is $i.i.d.N(0, \phi I_{1+N_R+N})$, ζ_t and ν_t are independently distributed, and ϕ is a scalar parameter.

The factors are identified by restrictions on the global and regional factor loadings (λ_i and γ_{ij}). The global factor enters all equations so λ_i is unrestricted. The regional factors are restricted to load on to only those variables in a region, so γ_{ij} is non-zero if country i is in region j and is zero otherwise. The scale of the factors is normalized setting $\lambda'\lambda/N = 1$ and $\gamma_j'\gamma_j/N_{R,j} = 1$, where $\lambda = (\lambda_1, ..., \lambda_N)'$, $\gamma_j = (\gamma_{1j}, ..., \gamma_{Nj})$, and N_R is the number of countries in region j. Therefore, the parameters of the model consist of $\lambda_i, \gamma_{ij}, \rho_i, \sigma^2_\varepsilon$ and ϕ.

The factor and idiosyncratic parameters (λ_i, γ_{ij} and ρ_i), $i = 1, ..., 22$ are estimated by

Gaussian maximum likelihood in a model in which values of $\sigma^2_\eta, \sigma^2_{\upsilon_j}$, and $\sigma^2_{\varepsilon_i}$ are allowed to break midway through the sample (1982: IV).[14] The pre- and post- break values of variances are modelled as unknown constants. The likelihood is maximized using the EM algorithm. The scale parameter ϕ is set equal to 0.04. Then smooth estimates of the factors and variances conditioning on the values of fixed parameters (λ_i, γ_{ij} and ρ_i), are computed using Gibbs sampling (see Stock and Watson (2010)).

3.4.2 Identification of Regions

The regional identification of the countries under investigation is not straight forward as most of them are the European countries. Thus we identify the regions both exogenously and endogenously and estimate the model with a number of different compositions of regions to test whether composition of regions does affect our results.

Endogenous Identification of Regions

The regional variations are independent of global variations in DFM-SV model so once global factor F_t is removed, regional co-movement would be observable. We estimate the regions after removing the common global component. To estimate the regions, we follow Stock and Watson (2010) and apply K-means method of clustering. First, to remove the common global component we estimated a single factor model,

$$\pi_{it} = \lambda_i F_t + u_{it} \tag{3.14}$$

$$F_t = F_{t-1} + \eta_t \tag{3.15}$$

$$u_{it} = \rho_{i1} u_{it-1} + \rho_{i2} u_{it-2} + \varepsilon_{it} \tag{3.16}$$

Where (η_t and ε_{it}) are independently distributed normal variables with zero mean and constant variances. In this specification residual u_{it} constitute the regional and idiosyncratic term which is obtained by subtracting the common global factor $F_t(\hat{u_{it}} =$

[14]The break is identified at 1982:IV because this is post oil shocks and heralds a new period of low inflation. The Moran's I statistics shown in figure 3.3 falls substantially in 1982. Moreover, 1982 is approximately half way through the sample period.

$\pi_{it} - \hat{\lambda}_i \hat{F}_t$). Then K-means method is implemented to estimate the constituents of the clusters. In general, the k-means method solves,

$$min_{[\mu_j, S_j]} \sum_{j=1}^{k} \sum_{i \epsilon S_j} (X_i - \mu_j)'(X_i - \mu_j) \tag{3.17}$$

Where, let $[Xi]$, $i = 1, ..., N$ be a T-dimensional vector and let μ_j be the mean vector of X_i if i is in cluster j. S_j is the set of indexes contained in cluster j. That is, the k-means method is the least-squares solution to the problem of assigning entity i with data vector X_i to group j.

We undertook initial cluster analysis to identify regions by taking k=3 with 400,000 starting random values. The objective function (3.17) was reduced approximately by 8 percent by moving from 3 to 4 but with 4 clusters number of countries was as few as two in one of the clusters. Moving from 4 to 5 clusters, the objective function was further minimized. We therefore choose k=5 as moving from 5 to 6 clusters there was marginal improvement in minimizing the value of objective function.

The composition of five regions is presented in second column of Table 3.3 and in Figure 3.5. As K-means clustering aims to group together the observations with the nearest means, it can be observed in Figure 3.5 that the inflation rates in each region are highly synchronized except for Korea in Region 1 and the U.K. in Region 4. Region 2 comprises the southern European countries with highest average inflation rates in our sample except Finland. Region 3 includes the western European countries with average inflation rates around 3 percent and Region 4 comprises U.K., Austria and Germany.

Average spatial correlation in inflation rates of countries within the estimated regions is shown in Figure 3.6. It can be seen in the figure that the regions, which include countries with strong intra regional linkages observe remarkable high spatial correlation in inflation rates. For instance, in Region 3 inflation rates are highly correlated across countries which includes BENELUX states (Belgium, Netherlands and Luxembourg) and Switzerland. The lowest correlation is shown among the countries in Region 2 (Finland, Greece and Portugal). However, it can be observed in all regions that inflation correlation across countries boosted in the late 1990s. This may be due to the transitional steps taken by the European countries to join common currency and surge of globalization.

Exogenous Identification of Regions

We identify three different compositions of regions to check if our results are robust across these compositions. In regional composition 1, we divide the countries into three regions. The first region includes the non European countries in our sample,[15] the second region consists of the founding member countries of the EMS (European Monetary System)[16] and the third region contains other European countries in our sample.[17] The full sample is split at 1979 when the EMS was formed to create an area of currency stability throughout the European community by encouraging countries to co-ordinate their monetary policy. To help the development of a single market, stable exchange rates were aimed by using an Exchange Rate Mechanism (ERM). By making this composition we aim to investigate whether the formation of EMS had affected the dynamics of inflation in the countries that joined together in 1979 to co-ordinate their monetary policies.

Inflation rates of regional composition 1 are plotted in Figure 3.7 and the spatial correlation in inflation rates of countries within each region is shown in Figure 3.8. The highest spatial correlation is observed in inflation rates of region 2 that includes the founding member countries of the European Monetary System. This implies that high co-movements in inflation rates across these countries are due to several measures taken by these countries to establish strong intra regional linkages (such as creation of "snake in the tunnel", European Monetary System, European Central Bank and creation of common currency area). Moreover, it can be seen in Figure 3.8 that co-movements of inflation rates increase sharply since the mid 1990s. The economic globalization plotted in Figure 3.17 also experiences a sharp rise since the mid 1990s. Hence, the strong movements in inflation rates may be attributed to rise in globalization.

[15] New Zealand, Korea, Japan, Australia, Canada, the U.S. and South Africa.

[16] Germany, Belgium, France, Luxembourg, Netherlands and Italy. See, Bofinger (2000) for a review of EMS and ERM.

[17] Finland, Switzerland, Sweden, the U.K., Norway, Austria, Greece, Portugal and Spain.

In the second composition, the countries in our sample are divided into three regions. We aimed to observe the effect of formation of the Euro on dynamics of inflation of the member countries. Thus as in the first composition, non-European countries in the sample are grouped together. The second region includes the countries who were early members of Euro Area (i.e. Germany, Belgium, France, Luxembourg, Netherlands, Italy, Finland, Austria, Portugal, Spain and Greece) and rest of the European countries in the sample are grouped together in region 3 (i.e. Sweden, U.K., Norway and Switzerland). The sample period is split into sub samples of 1961-1999 and 2000-2008 to observe the Euro effect on regional inflation.

Inflation rates of regional composition 2 are plotted in Figure 3.9 and the spatial correlation in inflation rates of countries within each region is shown in Figure 3.10. The co-movements in inflation rates of countries in region 2 (the early member countries of Euro) are observed to be increasing at the highest pace since the mid 1990s, implying that role of regional linkages is important in synchronization of inflation across countries.

Four regions are identified in the third composition. Member countries of the first region are same as in composition 1 and 2, the second region contains BENELUX states (i.e Belgium, Netherlands and Luxembourg), Germany, France and Italy, the third region includes Scandinavian countries (i.e. Finland, Norway and Sweden) and the rest of the European countries in our sample (Austria, Portugal, Spain, Greece, Switzerland and the U.K.) comprise Region 4. The sample period is split into sub samples of 1961-1999 and 2000-2008 to observe the Euro effect.

Inflation rates of regional composition 3 are plotted in Figure 3.11 and the spatial correlation in inflation rates of countries within each region is shown in Figure 3.12. Figure 3.12 shows that highest co-movements in inflation rates are observed in Region 2 followed bt Region 3. Again it is consistent with the fact that the countries which experience high correlation in inflation rates are more globalized economically as shown in Figure 3.17.

3.5 Empirical Results

3.5.1 Results for Split Sample Estimates of the Dynamic Factor Model without Stochastic Volatility

Endogenously determined regions

First, we report results from estimation of the dynamic factor model with constant disturbance variances given by equations (3.4) to (3.7) where the regions are endogenously determined. The purpose of this estimation is to examine the stability of the factor loading coefficients and the disturbance variances over the two split sub samples, 1961-1982 and 1983-2008.

We estimated two set of estimates. First, the unrestricted split sample estimates were produced by estimating the model separately for the two sub samples, 1961-1982 and 1983-2008 by maximum likelihood. Second, restricted split sample estimates were computed, where the factor loading coefficients λ_i and γ_{ij} and the idiosyncratic autoregressive coefficients ρ_i were restricted to be constant over the entire sample period, and the variances were allowed to change between the two sub samples. This restricted split model holds the coefficients of the mean dynamics constant but allows for changes in the variances.

The estimates for the restricted split-sample model are reported in Table 3.3. The factor loadings are normalized so that $\lambda'\lambda/N = 1$ and $\gamma_j'\gamma_j/N_{R_j} = 1$. The loadings on the factors show the sensitivity of inflation process to global and regional factors. The loadings on global factor are all positive (between 0.65 and 1.36) implying that inflation rates in all countries are effected by global factors and the inflation in Sweden, U.S., Belgium and Portugal are highly sensitive to global factors. The loadings of regional factor are also all positive except for Korea and Switzerland. The idiosyncratic disturbances exhibit a considerable persistence, with a median AR (1) coefficient of 0.92. In last two columns of Table 3.3, standard deviations of idiosyncratic disturbances for the two samples are reported as only the disturbance variances are allowed to change between the samples. It is shown that disturbance variance of all the countries except New Zealand falls. Table 3.4 reports the restricted split-sample estimates of the standard deviations of the factor innovations. It is shown that the standard deviations of global factor and regional factor 3 are slightly smaller in the second sample than the first. While, for region 1 and 2 it is increased and for region 4 and 5 it is decreased markedly. The increased volatility in region 1 is mainly contributed by New Zealand and South Africa which is also apparent in Figure 3.5, the figure of regional inflation. The larger decline in the standard deviation of factor innovations for region 4 is mainly because of the decline in the volatility of the U.K. and for region 5 it is mainly contributed by Italy, Spain and Japan whereas the dynamics for Austria, Germany, Australia and France are relatively stable.

Table 3.5 presents a decomposition of the variance of inflation rate between the two samples and is core evidence of our decomposition of global inflation using DFM-SV. Each column contains two estimates; first entries are the estimates from unrestricted split model and the second from the restricted split model. Estimates for unrestricted model were produced by estimating the model for sub samples (1961-1982 and 1983-2008) separately whereas in restricted model factor loading coefficients λ, γ and the idiosyncratic autoregressive coefficient ρ were restricted to be constant over entire sample period and their variances are allowed to change between the two sub samples. The first block of columns reports the fraction of the variance explained by the global factor ($R^2 - F$), regional factor ($R^2 - R$), and the idiosyncratic term ($R^2 - e$) for the first sample (1961-1982) and the second block reports these estimates for the second sample (1983-2008). The third block provides a decomposition of the change in variance of inflation between the two sub-samples attributable to changes in the contribution of global factor, regional factor and idiosyncratic term. In the last rows of this table summary statistics is given.

Before discussing the results, it is worth mentioning that the overall estimates of restricted and unrestricted split sample are similar. For example, for the earlier period the mean estimated R^2 explained by global factor, regional factor and idiosyncratic term in the first sample using unrestricted split model are 0.19, 0.16 and 0.66 respectively and these statistics using restricted split model are 0.14, 0.12 and 0.74. For further analysis, consider the estimates based on restricted model.

A number of features in the contents of Table 3.5 are noteworthy. First, the contribution of the idiosyncratic component in explaining the variance of inflation is highest followed by global and regional factors in sub samples. Second, the variance of inflation attributable to global factor substantially increases from the first sample to the second (the mean partial R^2 in the first period is 0.14 and in the second period it is 0.25) and the contribution of the country specific component falls (the mean partial R^2 in the first period is 0.74 and in the second it is 0.65) while the change in the contribution of the regional factor is fairly small. Third, the importance of the global factor, the regional factor and idiosyncratic component in inflation variance varies substantially across the countries in our sample. In the second sub sample, more than the half of the variance in inflation rates of U.S., Portugal, Canada, Belgium and Luxembourg is explained by the global and regional factors together whereas the contribution of idiosyncratic component for Australia, Korea and Greece is more than 90 percent in their inflation variance. However, for all the countries the importance of global factor is higher in the second sample than the first sample period. Fourth, the volatility of inflation has been markedly declined in all countries except New Zealand. The variance reduction ranged from 19 percent (Germany) to 93 percent (Korea) with a median reduction of 60 percent. This reduction in variance is mainly attributable to reduced volatility of idiosyncratic disturbance.

Our overall results generally agree with the findings presented by Neely and Rapach (2011). They find that global and regional factors account for 34 percent and 16 percent of the variability in inflation respectively while we estimate that 25 percent and 10 percent of the variance in inflation is explained by global and regional factors in sub sample 1983-2008. This may be because they estimate the dynamic factor model with fixed parameters. Secondly, we take into account the non-stationarity of inflation and impose unit root on the factors while they assume the inflation as a stationary process. Finally, their sample period and sample size also differs from ours.

Exogenously determined regions

Table 3.6 presents average decomposition of the variance of inflation rate of each region for three exogenously determined regional compositions between the two samples whereas the full results are given in Tables in Appendix A. Each column contains two estimates; first entries are the estimates from unrestricted split sample model and the second from the restricted split sample model.[18] Estimates for unrestricted model were produced as in the estimation with endogenously determined regions. The first block of columns reports the fraction of the variance explained by the global factor, regional factor, and the idiosyncratic term for the first sample and the second block reports these estimates for the second sample.

As it is mentioned in the discussion of the results with endogenously determined regions that estimates obtained from restricted and un restricted models are not very different. Thus here too we will consider the results based on restricted model for analysis. It is observed in Table 3.6 that average standard deviation of inflation has decreased in second sample for all the regions in all compositions.

The variance decomposition of inflation for composition 1 of the regions in first panel of Table 3.6 shows that the variance of inflation attributed to the global ($R^2 - F$) and regional factors ($R^2 - R$) for all three regions is substantially higher in second sample period (i.e. 1980-2008) as compare to the global R^2 in first sample period (1961-1979). The variance of inflation that is attributed to country specific factors is decreased over the sub samples. For example it decreased to 66 percent from 77 percent, 51 percent from 68 percent and to 66 percent from 90 percent for region 1, 2 and 3 respectively. It is remarkable to note that the regional R^2 is much higher (i.e. 20 percent) for the Region 2 that includes the founding members of the European Monetary System, whereas the global R^2 in all regions is almost the same. The inflation variance due to the global and regional factors in region 2 is almost 50 percent in second sub sample. This implies that the formation of the EMS and the steps followed to integrate the

[18]Unrestricted split sample model is estimated separately for the two sub samples. The restricted split sample model is estimated by restricting the factor loading coefficients λ and γ and the autoregressive coefficient ρ to be constant over the entire sample period (1961-2008) and the variances ($\sigma^2_\eta, \sigma^2_{\upsilon_j}$, and $\sigma^2_{\varepsilon_i}$) are allowed to change between two sub samples.

Europe such as the formation of European Monetary Union (EMU) contributed to synchronizing inflation rates in the region.

The Regional Composition 2 in Table 3.6 consists of three regions. the first region contains non-European countries in our sample as in Composition 1. The second region is group of the countries who joined the Euro early in 1999 and 2000, and the third region includes other European countries in our sample. A relevant sample break for this composition is in 1999 when single currency, the Euro was introduced to examine the regional synchronization of inflation over the sub samples. The results show that standard deviation of inflation is substantially lower in the second sub sample. For example for Region 2, it has decreased to 0.85 from 2.10. It is noteworthy that the variance of inflation attributed to global factor almost more than doubled in the second sample for all regions (i.e. from 19 percent in 1961-1999 to 36 percent in 2000-2008 for region 1, from 15 to 39 percent for region 2 and from 16 to 40 percent for region 3). The regional R^2 for Region 1 decreased from 9 percent in first sample to 1 percent in the second sub sample that can be justified keeping in view the heterogeneous nature of the countries in the region.[19] However, contrary to our expectation the regional R^2 for region 2 remain unchanged over the sub samples. Surprisingly, for the region 3 inflation variance attributed to regional factor increased from 1 percent in first sample to 21 percent in the second sub sample. Another interesting point to note is that the country specific factor in inflation variance decreased to less than 50 percent for European countries (region 2 and 3) after 1999, whereas for non European countries it is higher than 60 percent.

The results for regional composition 3 are given in the last panel of Table 3.6 where the countries in sample are divided into four regions. First region's composition is same as in Composition 1 and 2, the second region is group of BENELUX states together with Germany, France and Italy. The third region is composed of Scandinavian countries and the fourth region contains other European countries in the sample. The sample time period is split into two sub samples of 1961-1999 and 2000-2008. The results verify the findings obtained from the estimation with other regional compositions that

[19] Where, Korea, New Zealand, Japan and Australia, South Africa, the U.S. and Canada are grouped together.

the importance of the global factor has significantly increased from the first to second sample period. The regional R^2 for the Region 2 and 3 is substantially increased while for Region 1 it decreased and for region 4 it remained fairy the same. Thus our results are robust across different regional compositions.

To summarize our results for this section, we find that inflation is more synchronized in the countries that have strong intra regional linkages. We find strong effects of the formation of the EMS on importance of the regional factor in explaining the variance of inflation in the member countries. In the first sample period (1961-1999) the country specific factor is dominant in explaining the variance of inflation in the European countries. However, in the second sample period global and regional factors dominate the country specific factors implying that inflation has become a global phenomenon with increased globalization.

3.5.2 Results for the DFM-SV Model

The results based on the DFM for split samples in section 3.5.1 show that the global factor has gained importance and role of country specific component has decreased in the second sample but the Dynamic Factor Model does not explain how the dynamics of inflation evolve over time. To understand the evolution of inflation dynamics in our sample countries, we estimate the DFM-SV, discussed in section 3.4.1. The DFM-SV allows for stochastic volatility in factors and idiosyncratic disturbances and helps understand the evolution of inflation dynamics. For this purpose, the factor loadings λ, γ, and ρ are fixed at the full-sample MLEs, and the filtered estimates of the factors and their time-varying variances are computed by Markov Chain Monte Carlo (MCMC). The results are presented and discussed in this section.[20]

The growth of the estimated global factor from the DFM-SV model is plotted in Figure 3.13 along with two other measures of global movements in the inflation rate i.e. the first principal component of the 22 inflation series, and the change in average inflation rate. The first principal component is an estimator of the inflation rate of the global

[20]The DFM-SV is estimated using endogenously determined regional composition.

factor in a single-factor model (Stock and Watson 2002) under the assumption that the average population factor loading for the global factor is non-zero(Forni and Reichlin 1998). It is clear from Figure 3.13 that estimates of the factor (the DFM-SV Estimate) and the first principal component follow approximately the same pattern as average inflation rate except some discrepancies in 1970-1980. Figure 3.14 presents the growth rates of the global and five regional factors, along with 1 standard deviation bands, where the standard deviation bands represent filtering uncertainty. The dynamics of inflation as shown in Figure 3.2 is reflected by the global factor. The high and volatile inflation in 1970s and moderate inflation since late 1980s is also visible in regional factor 3, 4 and 5. The regional factors show substantial variations across regions. We can observe that the volatility of the regional factors 4 and 5 is substantially decreased and for first and second regional factors it is decreased which is consistent with the results produced by split sample analysis presented in Table 3.5.

Figure 3.15 depicts the pattern of volatility in the global and regional factors by reporting the estimated instantaneous standard deviation of the factor innovations. The estimated volatility of the global factor is highest in 1970s which coincide with the oil prices shock and it falls sharply from mid 1980s to mid 1990s. Regional factors 1 and 5 are more volatile while the stochastic volatility of other regional factors is small in magnitude and has little time variations. High volatility of regional factor 5 during 1970s is mainly contributed by Italy and Japan (Mumtaz and Surico 2012). Moreover, volatility of the regional factor 5 is at maximum at approximately the same time when the volatility of the global factor is at peak in 1970s.

Figure 3.16 contains computed country by country instantaneous estimates of the standard deviation of innovation to the idiosyncratic disturbance and the partial R^2 attributable to the global and regional factors and to the idiosyncratic disturbance analogous to split sample analysis using DFM-SV. The results are consistent with those produced by split sample analysis in Table 3.5. It is evident in Figure 3.16 that fraction of the country-level variance of inflation explained by the global factor has increased over time (top right panel), the fraction attributed to the idiosyncratic disturbance has decreased (bottom right panel), and the fraction attributed to regional factor remains almost unchanged (bottom left panel). Moreover, the volatility of the idiosyncratic disturbance has markedly decreased over time (top left panel).

The DFM-SV model explains how the global factor, the regional factor, and the idiosyncratic disturbance evolve over time which was not explained by split sample analysis. The patterns in Figure 3.16 shows the evolution of the importance of the global regional and the country specific factors in explaining the variance of inflation over time. The importance of global factor and idiosyncratic component has fluctuated over time. The important feature depicted in the Figure 3.16 is that though the contribution of idiosyncratic component is dominant in explaining the variance of inflation yet they are loosing importance over time and the global factor is gaining importance. It is apparent in Figure 3.16 that a sharp rise in the contribution of the global factor at first oil price shock coincides with a fall in the importance of idiosyncratic disturbance. Thereafter, global factor gains importance and is highest in late 1980s. The contribution of the global factor in explaining the variance in inflation is again low in mid-1990s where the contribution of idiosyncratic component is high and thereafter the global factor is becoming more important while the country specific factors are loosing their importance which verifies our results based on split sample analysis.

The average contribution of the regional factors in inflation volatility is small in magnitude and has fluctuated over time which is consistent with the results produced in split sample analysis where we showed that on average, they explain only around 10 percent of the variation in inflation. However, split sample analysis show that the regions that include countries with strong intra-regional linkages observe increased synchronization of inflation rates since late 1990s. The idiosyncratic standard deviation has declined over time with a break at mid 1970s, and to a lesser extent at mid 1980s.

3.6 Co-movements of Inflation Rates and Economic Globalization

Substantial co-movements of inflation rates across countries can be attributed to various factors such as common macroeconomic shocks, common monetary policy responses to these shocks and increased globalization. Wang and Wen (2007) investigate the role of common oil price shocks and monetary policy in the co-movements of inflation in OECD countries and argue that common oil price shocks and common monetary policy responses do not fully explain the international synchronization of inflation rates. The increased globalization may be an important factor in synchronizing inflation rates across countries.

Globalization may affect inflation directly and indirectly through various channels. Trade openness affect inflation directly due to lower import prices and indirectly due to increased competitive pressures, lower mark ups and reduced pricing powers of domestic firms. More over, the sensitivity of domestic inflation to domestic output gap and foreign output gap has changed.[21]

In our context, it is interesting to examine whether the larger variance of inflation attributed to international factors is associated with greater economic globalization of a country. We used the measure of economic globalization based on KOF index of globalization (Dreher et al. (2008)).[22] The index of economic globalization has two dimensions, i.e. actual flows and restriction on capital and trade. The actual flows include data on trade (sum of county's imports and exports), Foreign direct investment, portfolio investment(sum of a country's stock of assets and liabilities) and income payments to foreign nationals (all as percent of GDP). The sub indices of restrictions include restrictions on trade and capital using hidden import barriers, mean tariff rates, taxes on international trade (as a share of current revenue) and an index of capital account restrictions. Given a certain level of trade, a country with higher revenues from tariffs is considered as less globalized.

[21] For detailed discussion on this, see Chapter 2.
[22] KOF index covers the economic, social and political dimensions of globalization.

Economic globalization of the countries in our sample is plotted in Figure 3.17. The plot shows a progressive increase in economic globalization of all the countries with a strong boost since mid-1980s. However, since early 2000s this pace has slowed down. The gap between less globalized and most globalized countries has decreased over time. Luxembourg, Belgium and Netherlands (BENELUX states) are top three most globalized economies respectively and Korea and Japan are amongst the least globalized countries in our sample over the entire sample period.

The international common factor in inflation variance is computed by adding the global and regional factors reported in Table 3.5 for the two sub sample periods, 1961-1982 and 1983-2008. To associate economic globalization with common factor, average economic globalization for these periods is used for each country. The relationship between international common factor in inflation and economic globalization for sub samples is shown in Figure 3.18. The plot a in Figure 3.18 shows a very small positive relationship between common factor and economic globalization whereas the plot b in Figure 3.18 shows a positive relationship between economic globalization and common factor in inflation. This reflects that higher international factor in explaining the variance of national inflation rates is associated with higher economic globalization. This phenomenon is more evident over the sample period 1983-2008, the period of increased globalization.

We model the international common factor in national inflation rates as a function of globalization and estimate the following equation using OLS

$$\pi_i^F = \alpha + \beta g_i + \epsilon_i \tag{3.18}$$

where π_i^F is common factor in inflation rate of each country i, g_i is economic globalization for each country and ϵ_i is error term. Both are expressed in percentage terms. The equation is estimated for sample periods 1961-1982 and 1983-2008. The results are summarised in Table 3.7.

Economic globalization turns out to be positive but insignificant for the first sample period, 1961-1982 with R^2 equals 0.7. However, for the second sub sample, 1983-2008, economic globalization turns out to be positive and highly significant where R^2 is 0.48. This shows that one percentage increase in globalization leads to an increase of 1.17 percentage points in the common factor in national inflation rates (the variance in national inflation rate explained by international common factor). Hence, our results support the view that inflation rates are internationally synchronized due to increased globalization. The higher a country is globalized economically, the higher is the role of global factor in explaining the variance of its inflation rate. Insignificance of economic globalization in the first sample period and high significance in the second sample period lend support to our earlier finding that importance of international factors has increased in explaining the variance of inflation over time as a result of increased globalization.

3.7 Conclusion

In this Chapter, we estimate the DFM-SV to understand the underlying source and nature of co-movement in inflation across the OECD countries and decompose the inflation rates of 22 OECD countries into global factor, regional factors and the idiosyncratic disturbance component.

We show that most of the variance in inflation is explained by a national factor. However, role of the global factor in explaining the variance of inflation has increased over time while the national factor has been losing its contribution. The variance of inflation attributable to the regional factor has increased for the countries that have established strong intra regional linkages. For the European countries, global and regional factors together become dominant in explaining the variance of inflation while the national factor becomes less important (less than 50 percent) since 1999.

In addition, we find that the volatility of inflation attributable to the global and national factor varies substantially across countries. For the U.S. more than 50 percent of the variance in inflation is explained by the global factor while for Korea, Greece and Australia more than 90 percent of the variance in inflation is explained by the country specific factors. Our results are in line with the results produced by Neely and Rapach (2011) and partially agree with Mumtaz and Surico (2012) to the extent that they also find national factor as an important factor in explaining the variance of inflation. The volatility of inflation has markedly declined in most countries which is mainly attributable to reduced volatility of idiosyncratic disturbance term.

We find that the formation of the EMS and the steps followed to integrate the Europe such as the formation of European Monetary Union (EMU) and adopting the Euro as common currency, contributed in synchronizing the inflation rates in the region. The contribution of regional factor in explaining the variance of inflation in the region that consists of the EMS founding members is higher in Post-EMS period. We find that the importance of the country specific factor decreases to less than 40 percent from more than 70 percent after 1999 in the European countries. This reflects the synchronization of inflation due to the Euro effect. Furthermore, we showed that the high co-movements of inflation rates across countries are positively related to economic globalization. This relationship has become stronger since 1999. The more a country is globalized economically, the higher variance of its inflation rate is attributable to international factors.

We conclude that the global factor plays an important role in volatility of inflation rates and has gained importance over time. The countries without strong regional linkages experience dominant national conditions and little role of regional factors in explaining the variance of inflation. However, the European countries have developed strong regional linkages over time. Consequently, regional factors have gained importance over time and national factors are dominated by regional and global factor since the late 1990s in the European countries. The more a country is globalized economically, the higher is the role of global factor in explaining the variance of its inflation rate. The importance of international factors has increased in explaining the variance of inflation over time as a result of increased globalization.

Table 3.1: Inflation rates: Summary statistics

Country	Average inflation	Standard Deviation of inflation		95 percent confidence interval for largest AR root		Unit Root Test		
						DF-GLS Test Statistic	Ng and Perron(2001)Test	
		1961-1982	1983-2008	Lower	Upper		MZa	MZt
Austria	3.55	0.93	0.5	0.93	1.02	-1.75	-6.01	-1.71
Australia	5.18	1.06	0.88	0.92	1.02	-2.04*	-7.74	-1.96
Belgium	3.83	0.83	0.56	0.92	1.02	-1.31	-3.55	-1.3
Canada	4.16	0.69	0.68	0.94	1.02	-1.2	-2.86	-1.18
Switzerland	2.97	0.79	0.52	0.9	1.01	-2.14*	-8.92*	-2.01*
Germany	2.9	0.51	0.47	0.91	1.01	-2.01*	-8.64*	-2.06*
Spain	7.39	1.64	0.64	0.95	1.02	-0.91	-1.76	-0.93
Finland	5.21	1.29	0.49	0.93	1.02	-1.52	-4.91	-1.56
France	4.68	0.77	0.4	0.97	1.02	-1.11	-2.37	-1.09
UK	5.58	1.53	0.58	0.94	1.02	-1.46	-4.45	-1.48
Greece	9.32	2.1	1.02	0.95	1.02	-1.22	-3.08	-1.24
Italy	6.58	1.37	0.45	0.97	1.02	-0.89	-1.64	-0.91
Japan	3.51	1.58	0.52	0.92	1.02	-2.04*	-8.20*	-2.02*
Korea	8.66	4.03	0.98	0.89	1.01	-2.57**	-13.19*	-2.54*
Luxembourg	3.63	0.71	0.61	0.92	1.02	-1.49	-4.77	-1.54
Netherlands	3.66	1.06	0.44	0.94	1.02	-0.93	-1.82	-0.93
Norway	4.93	1.31	0.79	0.93	1.02	-1.17	-2.58	-1.09
NewZeland	6.17	0.99	1.42	0.95	1.02	-1.17	-2.85	-1.17
Portugal	9.36	3.31	1.16	0.95	1.02	-1.06	-2.343	-1.08
Sweden	4.96	1.2	0.85	0.93	1.02	-1.41	-4.17	-1.42
South Africa	8.46	1.41	1.31	0.94	1.02	-0.84	-1.72	-0.73
U.S.	4.15	0.76	0.54	0.89	1.1	-1.62	-6.22	-1.7

Notes: The 95 percent confidence interval for the largest autoregressive root in column 4 is computed by inverting the ADF tstatistics, computed using 4 lags. The column five reports the Elliott-Rothenberg-Stock DF-GLS test statistics. The final column presents the Ng and Perron (2001) MZa and MZt test statistics. The asteriks * and ** denotes rejecting unit root at 5 and 1 percent level of significance respectively.

Table 3.2: Cross-country inflation correlation

	Australia	Austria	Belgium	Canada	Switzerland	Germany	Spain	Finland	France	U.K	Greece	Italy	Japan	Korea	Luxembourg	Netherlands	Norway	N.Zealand	Portugal	Sweden	U.S	S.Africa
Australia	1	0.62	0.78	0.84	0.44	0.49	0.76	0.78	0.76	0.79	0.66	0.82	0.53	0.35	0.73	0.52	0.75	0.84	0.76	0.72	0.71	0.59
Austria		1	0.84	0.66	0.74	0.83	0.68	0.8	0.78	0.78	0.41	0.73	0.8	0.55	0.8	0.8	0.67	0.53	0.57	0.69	0.62	0.24
Belgium			1	0.79	0.64	0.74	0.75	0.86	0.85	0.81	0.49	0.83	0.71	0.51	0.94	0.8	0.71	0.63	0.69	0.72	0.68	0.35
Canada				1	0.55	0.61	0.79	0.81	0.89	0.81	0.67	0.85	0.56	0.51	0.75	0.62	0.79	0.79	0.76	0.8	0.86	0.54
Switzerland					1	0.82	0.41	0.61	0.57	0.55	0.41	0.49	0.7	0.46	0.59	0.65	0.5	0.35	0.37	0.59	0.49	0.22
Germany						1	0.57	0.66	0.69	0.7	0.43	0.65	0.69	0.51	0.75	0.76	0.53	0.39	0.47	0.65	0.61	0.25
Spain							1	0.8	0.82	0.78	0.56	0.88	0.59	0.49	0.72	0.59	0.74	0.75	0.8	0.8	0.66	0.44
Finland								1	0.83	0.84	0.5	0.82	0.75	0.64	0.8	0.74	0.76	0.68	0.69	0.76	0.68	0.36
France									1	0.84	0.6	0.92	0.67	0.59	0.82	0.69	0.8	0.77	0.8	0.8	0.82	0.41
U.K										1	0.53	0.82	0.71	0.62	0.76	0.74	0.72	0.75	0.68	0.79	0.81	0.43
Greece											1	0.71	0.28	0.17	0.48	0.17	0.55	0.62	0.72	0.68	0.61	0.83
Italy												1	0.6	0.53	0.82	0.6	0.77	0.77	0.82	0.82	0.77	0.55
Japan													1	0.63	0.6	0.74	0.54	0.41	0.43	0.56	0.55	0.05
Korea														1	0.46	0.62	0.49	0.38	0.25	0.51	0.56	0.02
Luxembourg															1	0.75	0.68	0.58	0.69	0.71	0.64	0.34
Netherlands																1	0.54	0.43	0.45	0.55	0.56	0.02
Norway																	1	0.82	0.66	0.78	0.64	0.51
N.Zealand																		1	0.72	0.73	0.68	0.6
Portugal																			1	0.77	0.64	0.59
Sweden																				1	0.71	0.55
U.S																					1	0.46
S.Africa																						1

Note: Mean Correlation = 0.64, Standard Deviation of correlation = 0.17)

Table 3.3: Maximum Likelihood Estimates, restricted split sample estimation

Country	**Region**	λ	γ	ρ	σ_ε**(61−82)**	σ_ε**(83−08)**
U.S	1	1.32	0.24	0.95	0.61	0.37
Canada	1	1.03	0.88	0.9	0.61	0.45
New Zealand	1	0.88	1.75	0.89	0.91	1.2
Norway	1	0.74	1.26	0.78	1.21	0.57
Sweden	1	1.36	0.49	0.87	1.06	0.73
South Africa	1	0.86	1.12	0.94	1.32	1.2
Korea	1	0.86	-0.11	0.87	3.99	1.01
Finland	2	0.86	0.39	0.93	1.25	0.4
Portugal	2	1.2	1.67	0.93	3.21	0.85
Greece	2	0.88	0.27	0.97	2.04	1.02
Belgium	3	1.32	1.37	0.78	0.55	0.29
Luxembourg	3	1.2	1.4	0.85	0.45	0.38
Netherlands	3	0.78	0.27	0.92	1	0.37
Switzerland	3	1.18	-0.31	0.92	0.66	0.38
Germany	4	0.88	0.58	0.92	0.31	0.37
Austria	4	0.9	0.53	0.75	0.78	0.41
UK	4	1.26	1.54	0.94	1.23	0.51
Japan	5	0.78	1.59	0.84	1.03	0.47
Italy	5	0.77	1.28	0.97	1.02	0.39
Spain	5	0.65	0.72	0.95	1.6	0.58
France	5	0.98	0.51	0.95	0.53	0.35
Australia	5	0.82	0.26	0.95	0.98	0.85

Notes: Estimates are restricted split-sample MLEs of the dynamic factor model with innovation variances that are constant over each sample but differ between samples. λ is the factor loading on global factor, γ is factor loading on regional factor and ρ is autoregressive coefficient of disturbance term. $\sigma_\varepsilon(61-82)$ is standard deviation of disturbance term over the sample period 1961-1982, $\sigma_\varepsilon(83-08)$ is standard deviation of distuebance term over the sample period 1983-2008. Regions are identified by K-means clustering.

Table 3.4: Restricted split estimates of the standard deviations of factor shocks for global and regional factors

	1961-1982	**1983-2008**	**Change**
Global Factor	0.34	0.3	-0.04
Region 1	0.18	0.35	0.17
Region 2	0.01	0.46	0.45
Region 3	0.26	0.21	-0.05
Region 4	0.41	0.02	-0.4
Region 5	0.66	0.01	-0.65

Notes: Restricred split sample estimates of standard deviation of factor shocks for global and regional shocks.

Table 3.5: Variance decomposition of inflation based on unrestricted and restricted split sample estimation of the Dynamic Factor Model, 1961-1982 and 1983-2008.

Country	**Region**	**1961-1982**				**1983-2008**				**Decomposition of $(Var_{61-82} - Var_{83-08})/Var_{83-08}$**			
		σ	R^2-F	R^2-R	R^2-e	σ	R^2-F	R^2-R	R^2-e	Total	F	R	e
South Africa	1	1.80 2.66	0.27 0.05	0.01 0.02	0.72 0.93	2.52 2.52	0.01 0.04	0.19 0.10	0.80 0.86	0.97 -0.10	-0.25 -0.01	0.36 0.07	0.86 -0.16
New Zealand	1	1.87 1.94	0.19 0.10	0.06 0.11	0.75 0.79	2.60 2.66	0.01 0.04	0.22 0.22	0.77 0.74	0.92 0.88	-0.18 -0.02	0.37 0.31	0.73 0.60
U.S.	1	1.50 1.49	0.38 0.36	0.35 0.00	0.27 0.63	0.99 1.08	0.53 0.53	0.09 0.03	0.38 0.45	-0.57 -0.47	-0.15 -0.09	-0.31 0.01	-0.11 -0.40
Korea	1	7.04 7.51	0.05 0.01	0.15 0.00	0.80 0.99	1.79 1.97	0.03 0.07	0.00 0.00	0.96 0.93	-0.94 -0.93	-0.04 0.00	-0.15 0.00	-0.74 -0.93
Norway	1	2.22 2.27	0.06 0.05	0.00 0.04	0.94 0.91	1.40 1.43	0.05 0.09	0.44 0.40	0.51 0.50	-0.6 -0.6	-0.04 -0.01	0.17 0.12	-0.74 -0.71
Sweden	1	2.01 2.21	0.13 0.18	0.00 0.01	0.87 0.82	1.64 1.63	0.24 0.25	0.03 0.05	0.73 0.70	-0.34 -0.46	0.03 0.04	0.02 0.02	-0.38 -0.43
Canada	1	1.36 1.40	0.15 0.25	0.15 0.05	0.70 0.69	1.13 1.23	0.25 0.25	0.30 0.26	0.46 0.49	-0.3 -0.22	0.03 -0.06	0.06 0.15	-0.38 -0.31
Finland	2	2.40 2.48	0.07 0.06	0.00 0.00	0.93 0.94	0.95 1.00	0.21 0.27	0.09 0.13	0.70 0.60	-0.84 -0.84	-0.03 -0.01	0.01 0.02	-0.82 -0.85
Portugal	2	5.52 6.24	0.09 0.02	0.00 0.00	0.91 0.98	2.26 2.37	0.10 0.09	0.30 0.43	0.61 0.48	-0.83 -0.86	-0.07 0.00	0.05 0.06	-0.81 -0.91
Greece	2	3.83 4.07	0.22 0.02	0.00 0.00	0.78 0.98	1.99 2.09	0.01 0.06	0.01 0.01	0.98 0.92	-0.73 -0.74	-0.21 -0.01	0.00 0.00	-0.52 -0.73
Belgium	3	1.67 1.52	0.31 0.35	0.67 0.22	0.02 0.43	1.05 1.11	0.61 0.50	0.09 0.27	0.30 0.23	-0.61 -0.47	-0.07 -0.08	-0.64 -0.08	0.10 -0.31
Luxembourg	3	1.37 1.38	0.23 0.35	0.12 0.28	0.65 0.36	1.12 1.17	0.62 0.38	0.08 0.26	0.30 0.36	-0.33 -0.29	0.18 -0,08	-0.06 -0.1	-0.45 -0.11
Netherlands	3	1.83 1.99	0.06 0.07	0.21 0.00	0.72 0.92	0.79 0.86	0.26 0.29	0.06 0.02	0.68 0.69	-0.81 -0.81	-0.02 -0.02	-0.20 0.00	-0.60 -0.80
Switzerland	3	1.56 1.51	0.24 0.29	0.01 0.01	0.75 0.70	0.97 1.03	0.61 0.47	0.35 0.02	0.04 0.51	-0.61 -0.53	-0.01 -0.07	0.13 0.00	-0.73 -0.46
Germany	4	0.98 0.98	0.30 0.38	0.36 0.25	0.34 0.37	0.89 0.88	0.46 0.36	0.00 0.00	0.54 0.64	-0.18 -0.19	0.08 -0.09	-0.36 -0.25	0.10 0.14
Austria	4	1.55 1.57	0.15 0.15	0.18 0.08	0.67 0.77	0.92 0.90	0.27 0.36	0.00 0.00	0.73 0.64	-0.64 -0.67	-0.05 -0.04	-0.18 -0.08	-0.41 -0.56
U.K.	4	2.94 2.84	0.22 0.09	0.18 0.20	0.60 0.70	1.11 1.25	0.25 0.37	0.00 0.00	0.75 0.63	-0.86 -0.81	-0.19 -0.02	-0.18 -0.2	-0.5 -0.58
Japan	5	3.17 2.90	0.28 0.03	0.16 0.54	0.56 0.43	0.97 0.99	0.09 0.22	0.00 0.00	0.91 0.78	-0.91 -0.88	-0.27 -0.01	-0.16 -0.54	-0.48 -0.34
Italy	5	2.63 2.69	0.20 0.04	0.55 0.40	0.25 0.56	0.77 0.89	0.43 0.27	0.05 0.00	052 0.73	-0.91 -0.89	-0.16 -0.01	-0.55 -0.40	-0.21 -0.48
Spain	5	3.09 3.29	0.03 0.02	0.15 0.08	0.82 0.90	1.18 1.20	0.08 0.11	0.06 0.00	0.85 0.89	-0.85 -0.87	0.02 0.00	-0.15 -0.08	-0.69 -0.78
France	5	1.38 1.40	0.33 0.23	0.08 0.23	0.59 0.54	0.76 0.91	0.47 0.42	0.02 0.00	0.51 0.58	-0.7 -0.58	-0.19 -0.05	-0.08 -0.23	-0.44 -0.30
Australia	5	2.01 2.02	0.21 0.08	0.03 0.03	0.77 0.89	1.71 1.72	0.02 0.08	0.95 0.00	0.02 0.92	-0.28 -0.27	-0.19 -0.02	0.66 -0.03	-0.75 -0.22
Mean		2.44 2.56	0.19 0.14	0.16 0.12	0.66 0.74	1.34 1.40	0.26 0.25	0.15 0.10	0.59 0.65	-0.5 -0.53	-0.08 -0.03	-0.05 -0.06	-0.36 -0.44
Percentiles													
0.1		1.37 1.40	0.06 0.02	0.00 0.00	0.27 0.43	0.79 0.89	0.01 0.06	0.00 0.00	0.30 0.45	-0.91 -0.88	-0.21 -0.08	-0.36 -0.25	-0.75 -0.85
0.25		1.55 1.51	0.09 0.04	0.01 0.00	0.59 0.56	0.95 0.99	0.05 0.09	0.01 0.00	0.46 0.50	-0.84 -0.84	-0.19 -0.06	-0.18 -0.1	-0.73 -0.73
0.5		1.87 2.02	0.20 0.08	0.12 0.04	0.72 0.77	1.11 1.17	0.24 0.25	0.06 0.02	0.61 0.64	-0.64 -0.6	-0.07 -0.02	-0.08 0.00	-0.48 -0.46
0.75		2.94 2.84	0.27 0.25	0.18 0.22	0.80 0.92	1.71 1.72	0.46 0.37	0.22 0.22	0.77 0.78	-0.33 -0.29	0.02 -0.01	0.06 0.02	-0.21 -0.30
0.9		3.83 4.07	0.31 0.35	0.36 0.28	0.91 0.98	2.26 2.37	0.61 0.47	0.35 0.27	0.91 0.92	-0.18 -0.19	0.03 0.00	0.36 0.12	0.10 -0.11

Notes: The first entry in each cell is computed using the unrestricted split sample estimates of the Dynamic Factor Model; the second entry is computed using restricted split sample estimates for which the factor loadings and idiosyncratic autoregressive coefficients are restricted to equal their full sample values. The first numeric column is the region of the country. The next block of the columns contains the standard deviation of inflation over 1961-1982 (σ) and the fraction of the variance attributed to global factor (R^2-F), the regional factor (R^2-R), and the idiosyncratic disturbance (R^2-e). The second block contains the same statistics for 1983-2008. The last block decomposes the relative change in the variance from the first to the second period. The first column in the last block is the Total of last three columns.

Table 3.6: Variance decomposition of inflation based on unrestricted and restricted split sample estimation of the Dynamic Factor Model, exogenously determined regional compositions.

	Region	σ	R^2-F	R^2-R	R^2-e	σ	R^2-F	R^2-R	R^2-e
			1961-1979				1980-2008		
Composition 1	1	2.72 2.85	0.22 0.17	0.15 0.07	0.64 0.77	1.78 1.86	0.23 0.23	0.14 0.11	0.63 0.66
	2	1.69 1.67	0.28 0.18	0.20 0.15	0.52 0.68	0.98 1.07	0.24 0.29	0.23 0.20	0.54 0.51
	3	2.81 3.00	0.14 0.10	0.11 0.00	0.75 0.90	1.53 1.60	0.23 0.22	0.11 0.13	0.67 0.66
			1961-1999				2000-2008		
Composition 2	1	2.49 2.47	0.19 0.19	0.09 0.09	0.72 0.71	1.35 1.45	0.44 0.36	0.13 0.01	0.43 0.63
	2	2.05 2.10	0.18 0.15	0.12 0.12	0.69 0.73	0.83 0.85	0.44 0.39	0.19 0.12	0.37 0.49
	3	1.88 1.89	0.17 0.16	0.07 0.01	0.75 0.84	1.09 1.09	0.52 0.40	0.18 0.21	0.31 0.40
			1961-1999				2000-2008		
Compostion 3	1	2.49 2.48	0.15 0.19	0.12 0.09	0.69 0.75	1.34 1.44	0.44 0.36	0.12 0.01	0.44 0.63
	2	1.43 1.43	0.27 0.22	0.15 0.17	0.57 0.62	0.85 0.85	0.43 0.38	0.25 0.23	0.32 0.40
	3	1.95 1.96	0.11 0.12	0.13 0.09	0.77 0.79	1.16 1.14	0.43 0.32	0.23 0.19	0.33 0.50
	4	2.64 2.70	0.16 0.12	0.13 0.13	0.72 0.75	0.82 0.88	0.57 0.47	0.13 0.11	0.30 0.42

Notes:Table shows the average variance decomposition of inflation rates of regions for three different regional compositions of sample countries where regions are exogenously determined (Full results are given in Table A.2, A.4 and A.6). the first entry in each cell is computed using the unrestricted split sample estimates of the dynamic factor model. The second entry is computed using restricted split sample estimates for which the factor loadings and idiosyncratic autoregressive coefficients are restricted to equal their full sample values. The first numeric column is the region. The next block of the columns contains the standard deviation of inflation over first sample period and the fraction of the variance attributed to global factor F, the regional factor R, and the idiosyncratic disturbance e. the second block contains the same statistics for the second sample period.

Regional Composition 1 is as follows; region 1 is group of non-European countries (i.e.New Zealand, Korea, Japan, Australia, Canada, the U.S. and South Africa), region 2 contains Germany, Belgium, France, Luxembourg, Netherlands and Italy (the founding members of European Monetary System) and region 3 includes other European countries in our sample (i.e. Finland, Switzerland, Sweden, U.K., Norway, Austria, Greece, Portugal and Spain). For this regional composition, we split the sample period into sub-samples of 1961-1979 and 1980-2008 to examine the effect of formation of European Monetary System on variance decomposition of inflation in regions.

Regional Composition 2; The first region in second composition comprises the same countries as in composition 1, region 2 includes the early member countries of Euro(i.e. Germany, Belgium, France, Luxembourg, Netherlands, Italy, Finland, Austria, Portugal, Spain and Greece) and rest of the European countries in our sample are grouped together in region 3 (i.e. Sweden, U.K., Norway and Switzerland). The sample period is split into sub samples of 1961-1999 and 2000-2008 to observe the Euro effect on regional factor.

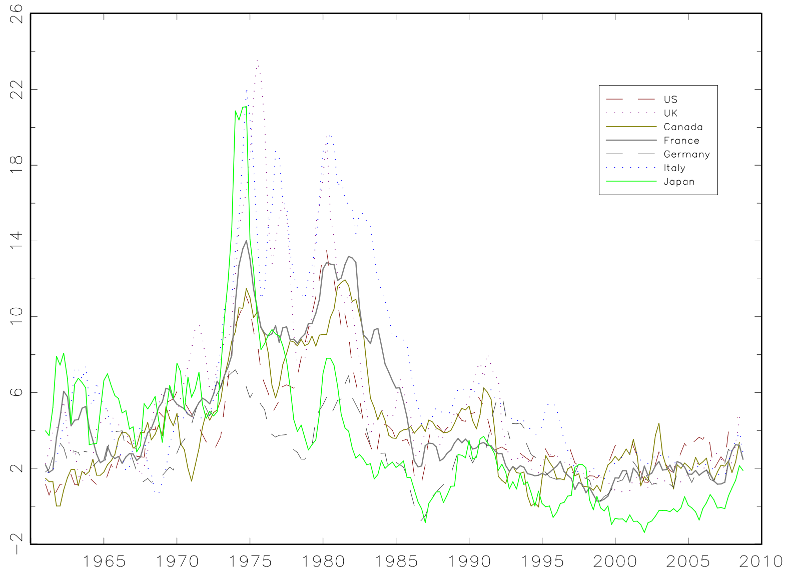
Regional Composition 3; In this composition we divide the sample countries into four regions. Members of the first region are same as in composition 1 and 2, the second region contains BENELUX states(i.e. Belgium, Netherlands and Luxembourg), Germany, France and Italy, the third region includes the Scandinavian countries (i.e. Finland, Norway and Sweden) and the rest of European countries in our sample (i.e. Austria, Portugal, Spain, Greece, Switzerland and the U.K.) comprise Region 4. The sample period is split into sub samples of 1961-1999 and 2000-2008 to observe the Euro effect.

Table 3.7: Common factors in inflation and economic globalization

$\pi_i^F = \alpha + \beta g_i + \epsilon_i$ (Number of observations = 22)			
Sample Period	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	$\boldsymbol{R^2}$
1961-1982	2.8	0.41	0.07
1983-2008	-50.8**	1.17***	0.48

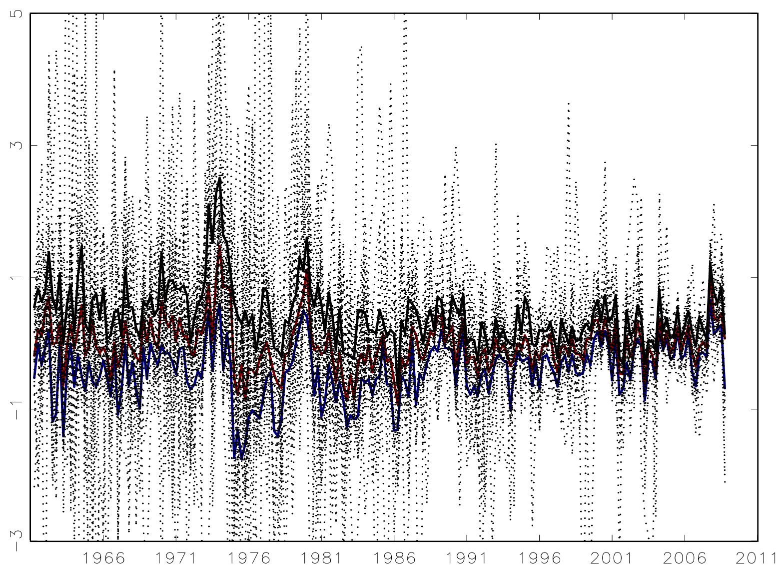
Notes: The table shows OLS estimates of the equation in top row, where π_i^F is estimated common factor(global and regional) shown in Table 3.5 and g is the measure of economic globalization based on KOF index of globalization 2011. *** and ** show level of significance at 1 and 5 percent, respectively.

Figure 3.1: Inflation rate of G-7 countries



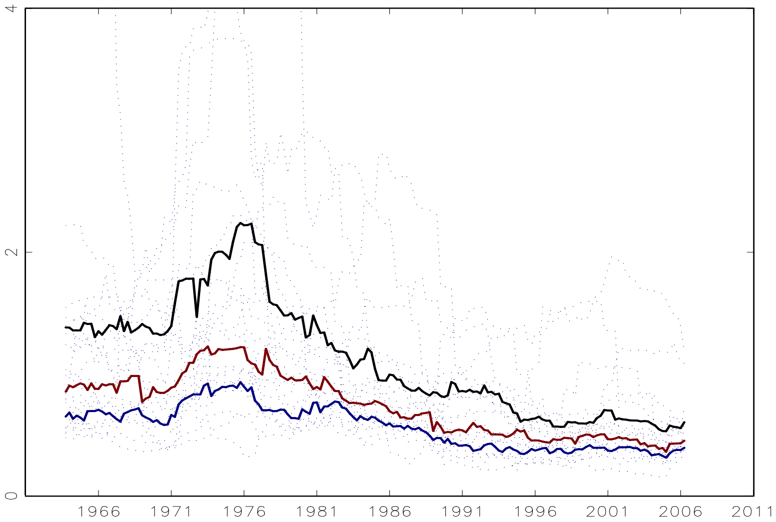
Note: The figure illustrates substantail co-movements in inflation rates across G-7 countries.

Figure 3.2: Change in inflation rates of 22 OECD countries.



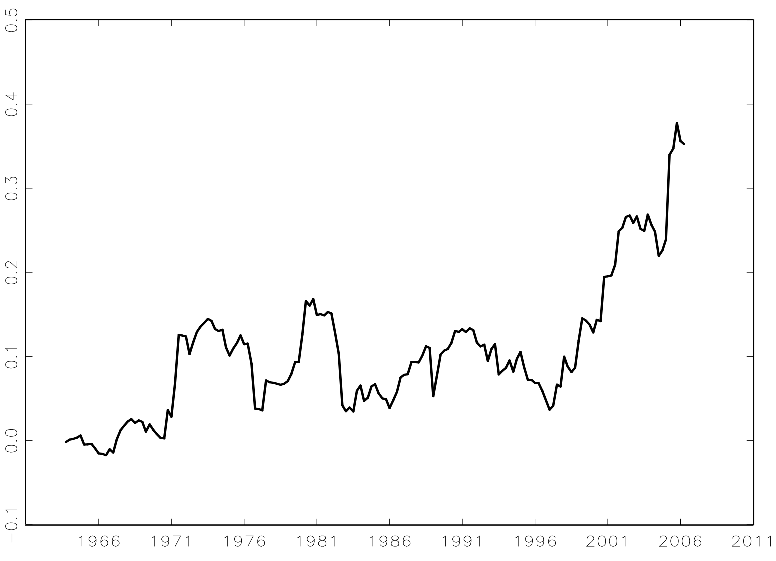
Note: The dotted lines are the first differenced inflation series of 22 OECD countries; The median, 25 percent, and 75 percent percentiles are in solid lines.

Figure 3.3: Rolling standard deviation (centred 21-quarter window) of the inflation rates for all countries.



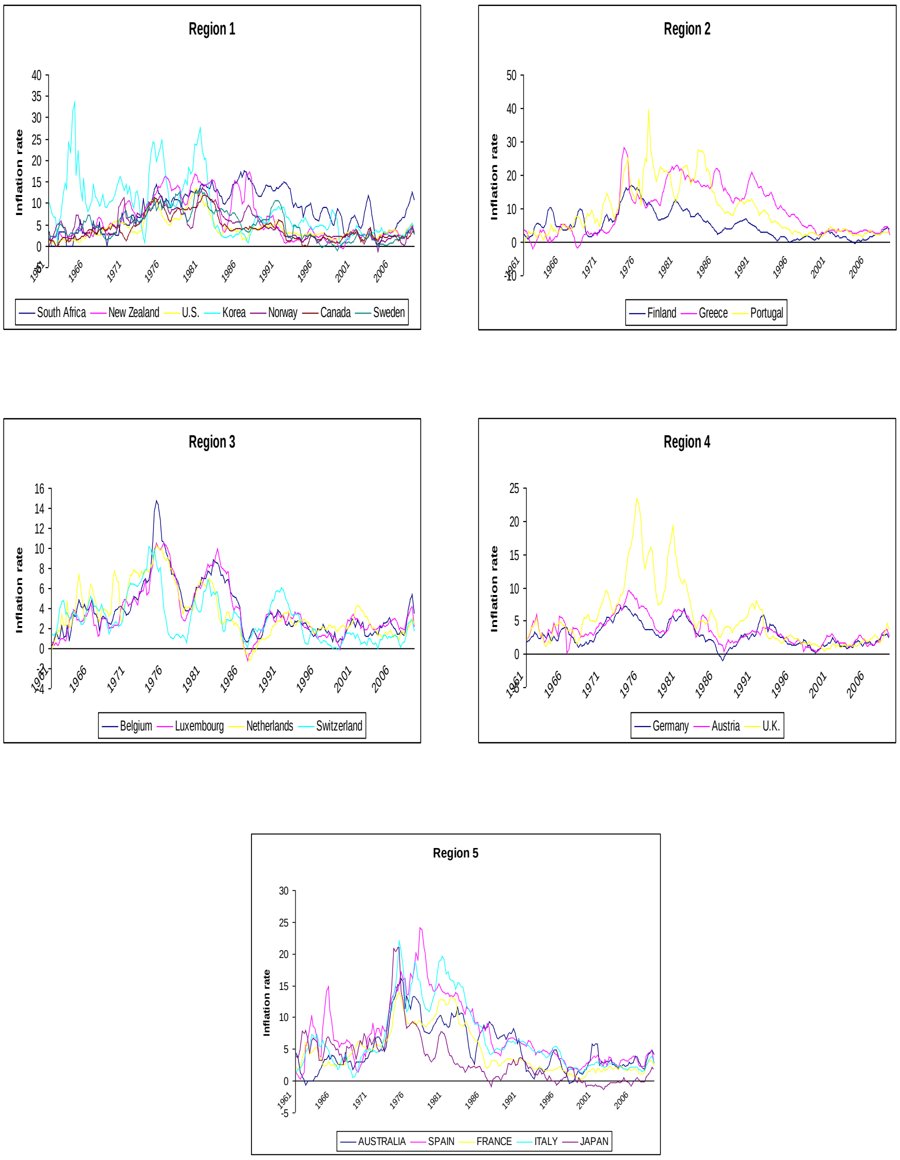
Note: The figure shows median, 25 percent, and 75 percent percentiles of rolling standard deviations of inflation for 22 OECD countries

Figure 3.4: Rolling average spatial correlation in the first differenced inflation rate across countries



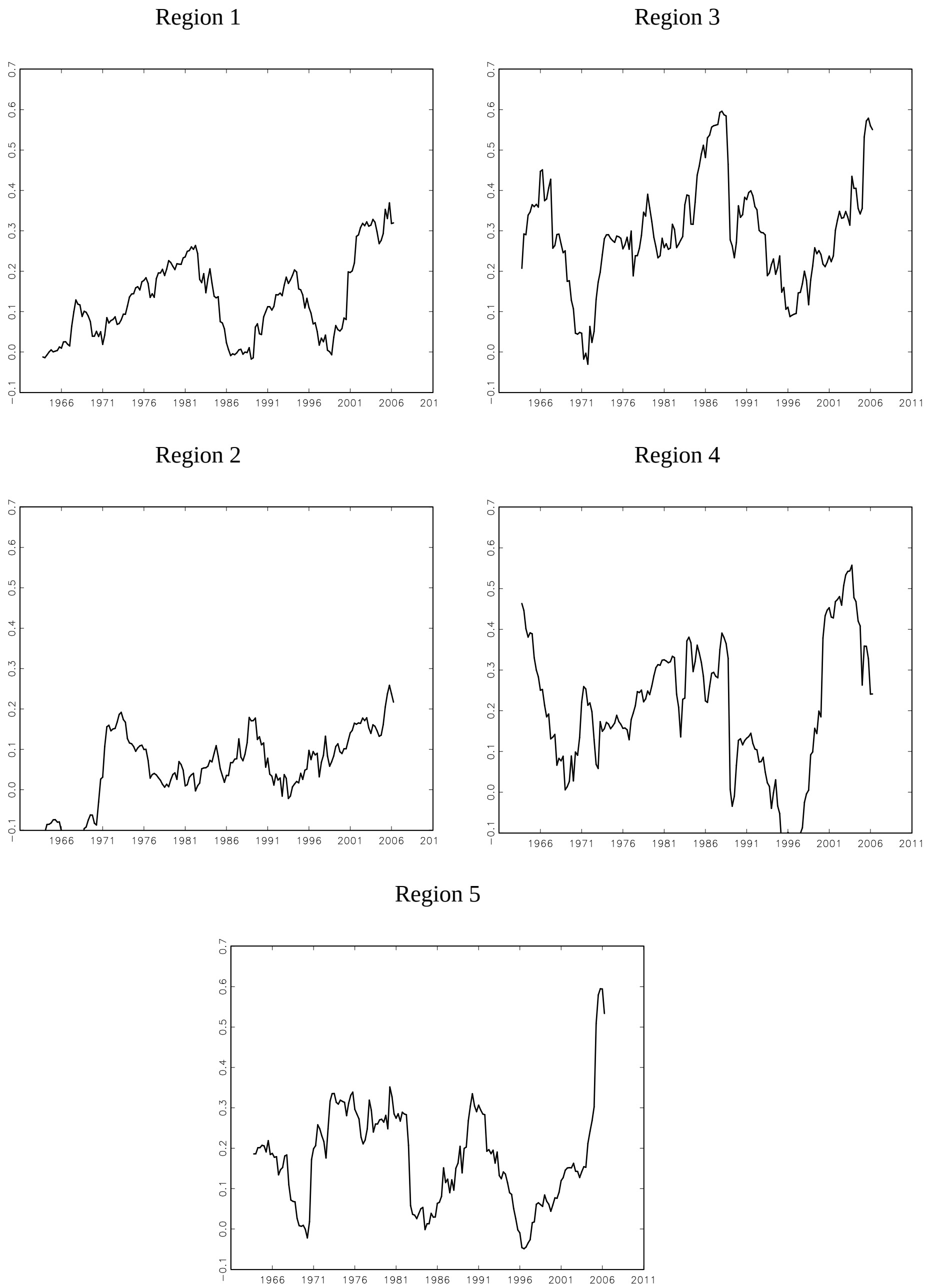
Note: Rolling average spatial correlation in inflation rates of 22 OECD countries as measured by the modified Moran's I statistics $\bar{I}_t$.

Figure 3.5: Inflation rates of endogenously determined regions



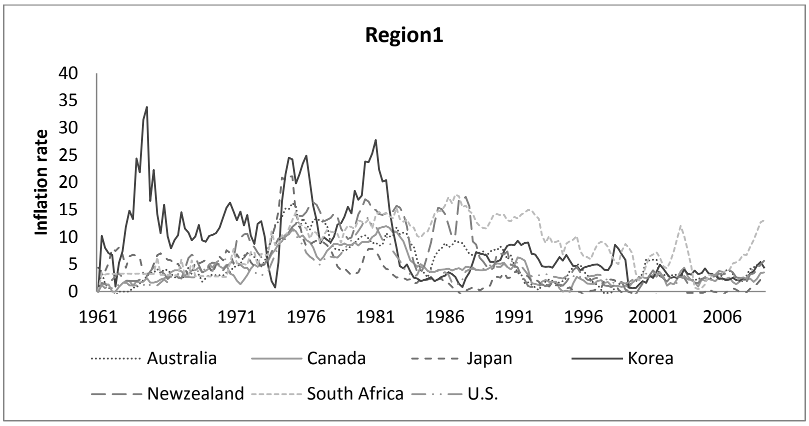
Note: The figure shows inflation rates of regions estimated using K-means clustering.

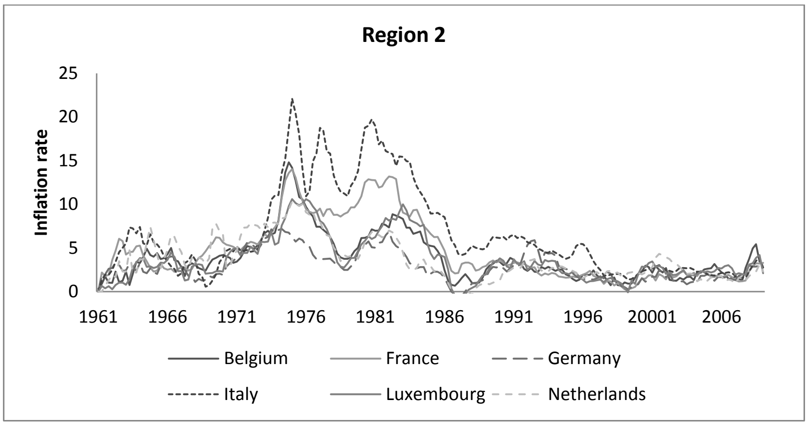
Figure 3.6: Average spatial correlation in inflation rates across countries within the endogenously determined regions

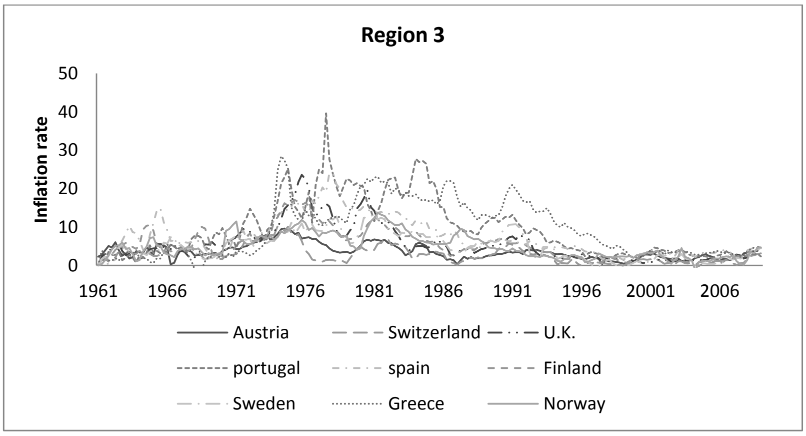


Note: Rolling average Spatial Correlation in inflation rates across countries within the Endogenously determined Regions. Region 1 includes South Africa, Newzealand, the United States, Korea, Norway, Canada and sweden, Region 2 consists of Finland, Greece and Portugal, Region 3 includes Belgium, Netherlands, Luxembourg and Switzerland, Region 4 consists of Germany, Austria and the United kingdom, and Region 5 consists of Australia, Spain, France, Italy and Japan.

Figure 3.7: Inflation rates of exogenously determined regions, Composition 1

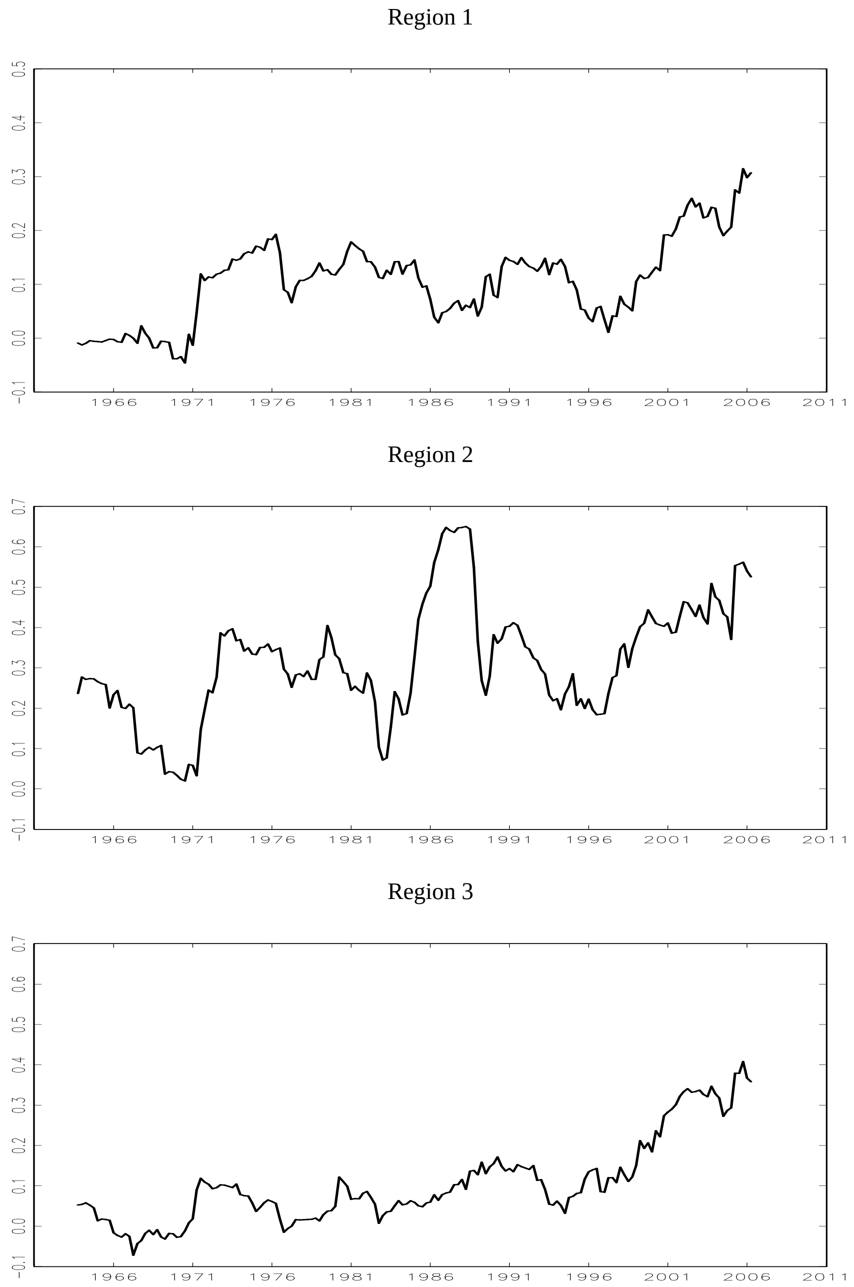






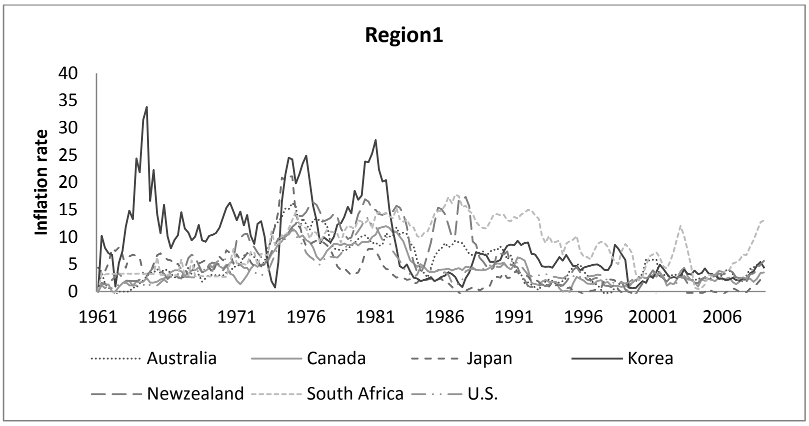
Note: This figure shows the inflation rates of exogenously determined regions where Region 1 is group of non-European countries (Australia, Canada, Japan, Korea, New Zealand, South Africa and the U.S.), Region 2 contains the founding members of European Monetary System (Belgium, France, Germany, Italy, Luxembourg, and Netherlands) and Region 3 includes other European countries in our sample (i.e. Austria, Switzerland, the U.K., Portugal, Spain, Finland, Sweden, Greece, and Norway).

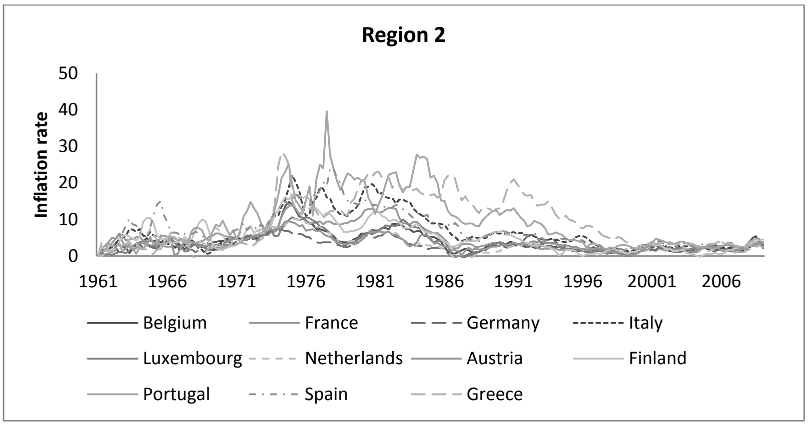
Figure 3.8: Average spatial correlation in inflation rates across countries within the exogenously determined regions, Composition 1

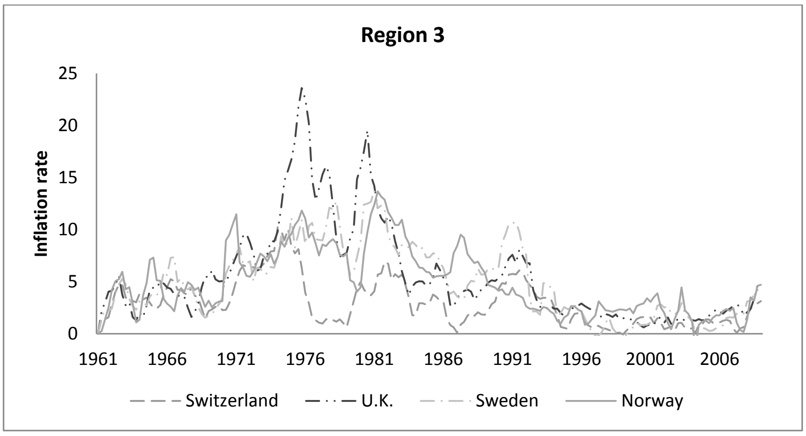


Note: Rolling average Spatial Correlation in inflation rates across countries within the Exogenously determined Regions. Region 1 is group of non-European countries (Australia, Canada, Japan, Korea, New Zealand, South Africa and the U.S.), region 2 contains Belgium, France, Germany, Italy, Luxembourg, and Netherlands (the founding members of European Monetary System) and region 3 includes other European countries in our sample (i.e. Austria, Switzerland, the U.K., Portugal, Spain, Finland, Sweden, Greece, and Norway).

Figure 3.9: Inflation rates of exogenously determined regions, Composition 2



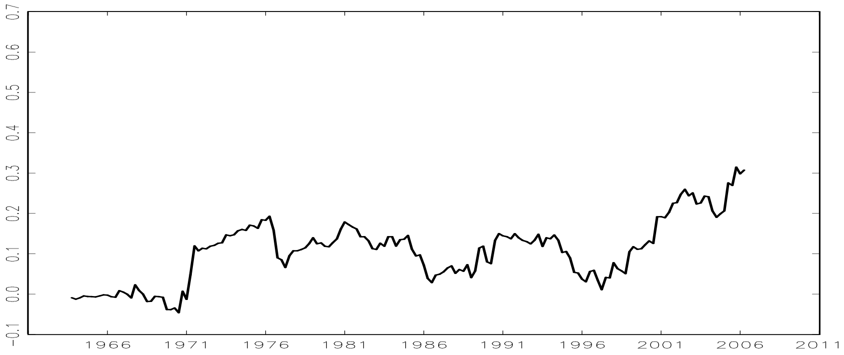




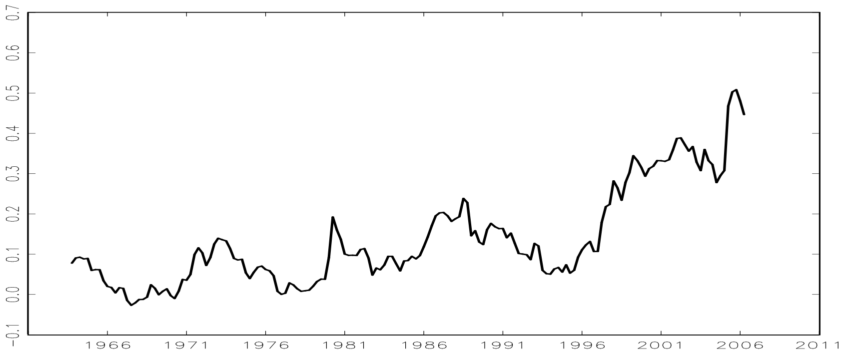
Note: This figure shows the inflation rates of exogenously determined regions where Region 1 is group of non-European countries (New Zealand, Korea, Japan, Australia, Canada, the U.S. and South Africa), Region 2 includes the early member countries of the Euro(Germany, Belgium, France, Luxembourg, Netherlands, Italy, Finland, Austria, Portugal, Spain and Greece) and rest of the European countries in our sample are grouped together in Region 3 (i.e. Sweden, U.K., Norway and Switzerland).

Figure 3.10: Average spatial correlation in inflation rates across countries within the exogenously determined regions, Composition 2

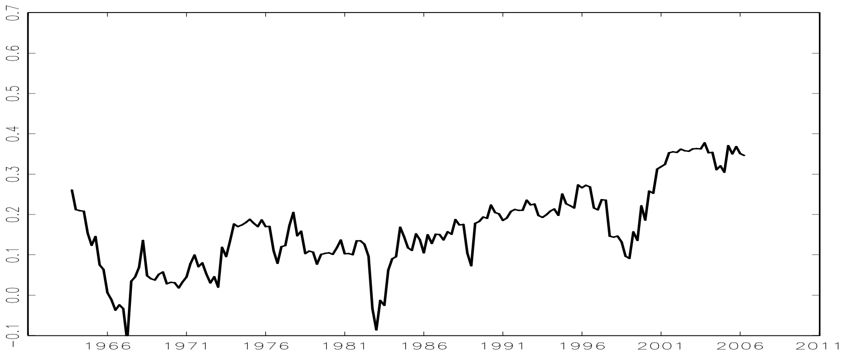
Region 1



Region 2

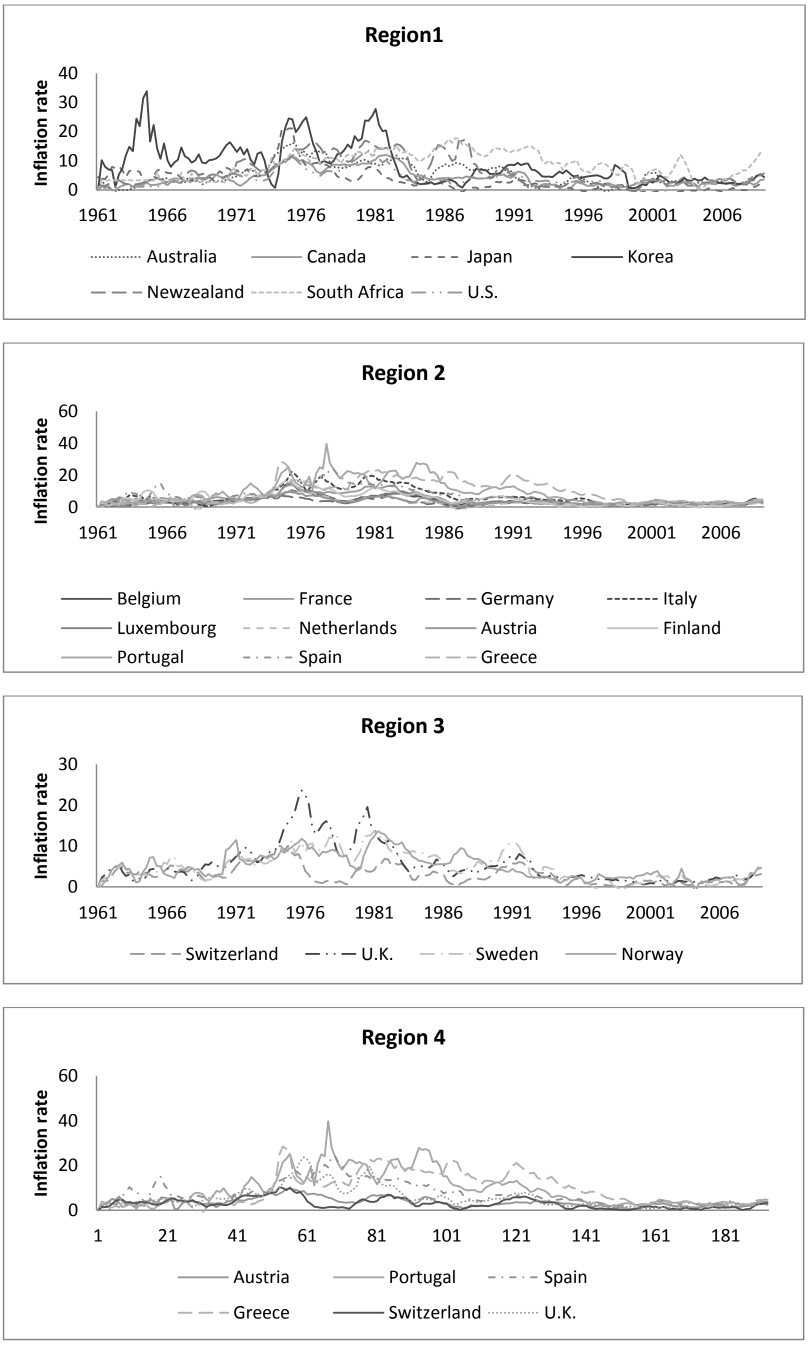


Region 3



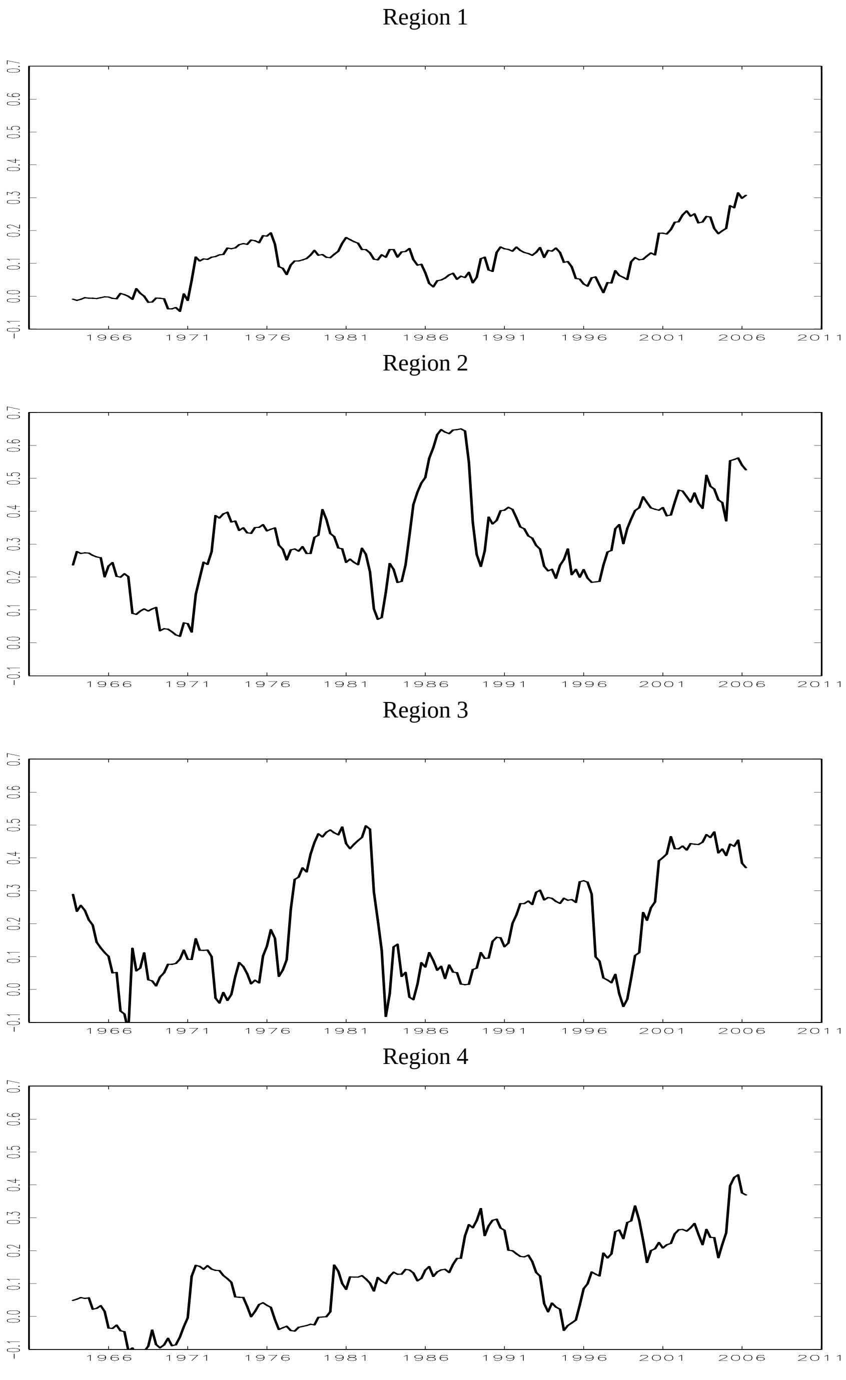
Note: Rolling average Spatial Correlation in inflation rates across countries within the Exogenously determined Regions where Region 1 is group of non-European countries (New Zealand, Korea, Japan, Australia, Canada, the U.S. and South Africa), Region 2 includes the early member countries of the Euro(Germany, Belgium, France, Luxembourg, Netherlands, Italy, Finland, Austria, Portugal, Spain and Greece) and rest of the European countries in our sample are grouped together in Region 3 (i.e. Sweden, U.K., Norway and Switzerland).

Figure 3.11: Inflation rates of exogenously determined regions, Composition 3



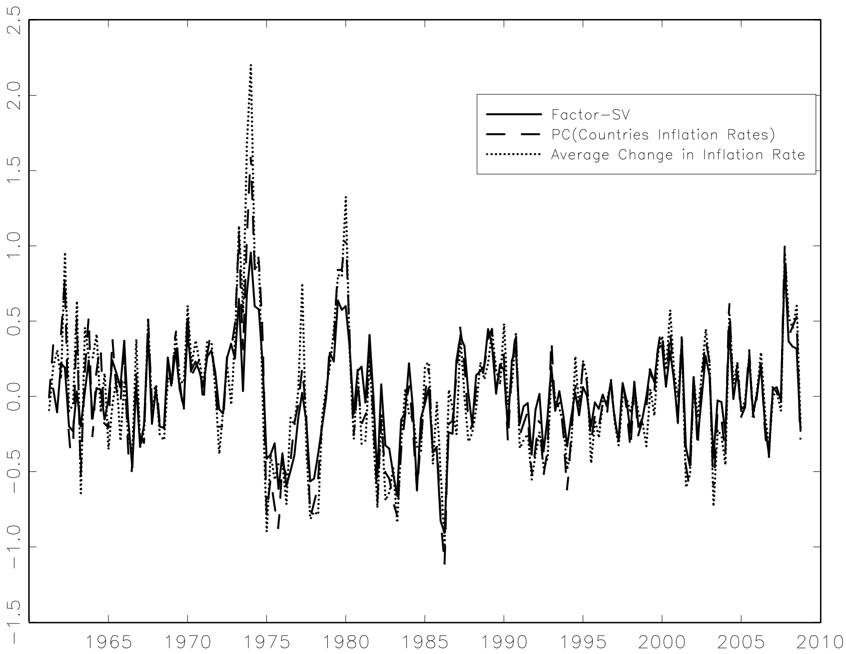
Note: This figure shows the inflation rates of exogenously determined regions where Members of the first region are same as in composition 1 and 2, the second region contains BENELUX states(Belgium, Netherlands and Luxembourg), Germany, France and Italy, the third region includes Scandinavian countries (Finland, Norway and Sweden) and the rest of European countries in our sample (Austria, Portugal, Spain, Greece, Switzerland and U.K.) comprise Region 4.

Figure 3.12: Average spatial correlation in inflation rates across countries within the exogenously determined regions, Composition 3



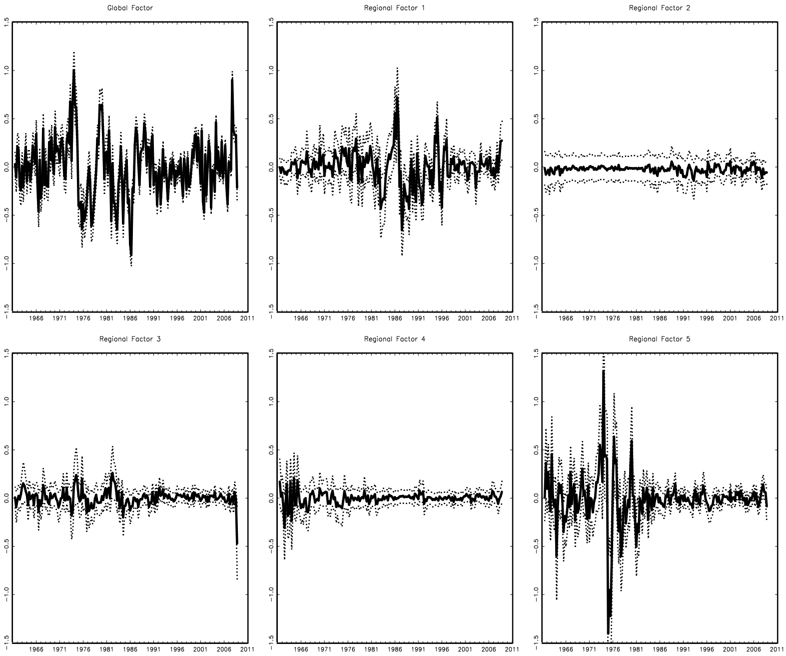
Note: Rolling average Spatial Correlation in inflation rates across countries within the Exogenously determined Regions where Members of the first region are same as in composition 1 and 2, the second region contains BENELUX states(Belgium, Netherlands and Luxembourg), Germany, France and Italy, the third region includes Scandinavian countries (Finland, Norway and Sweden) and the rest of European countries in our sample (Austria, Portugal, Spain, Greece, Switzerland and U.K.) comprise Region 4.

Figure 3.13: Comparison of global factor-sv, first principal component and average change in inflation rate



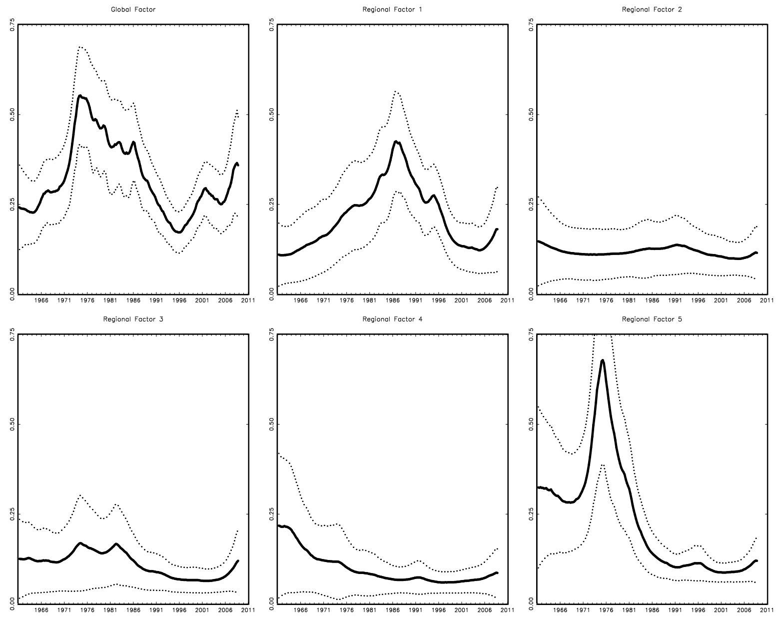
Notes: Comparison of DFM-SV filtered estimate of the global factor (solid line) to the first Principal component of the 22 countries inflation series, and average change in inflation rate (dotted line).

Figure 3.14: Change in the estimates of global and regional factors



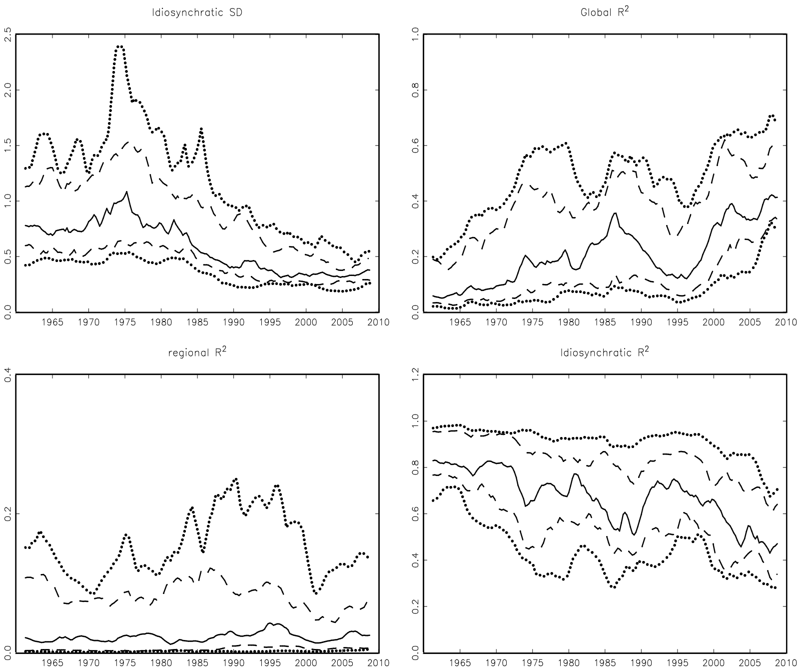
Notes: Change in the filtered estimates of the global factor (first panel) and the five regional factors (endogenously determined) from DFM-SV model, and standard deviation bands (dotted line). The top left diagram is the global factor, followed by regional factors.

Figure 3.15: Standard deviations of factor innovations



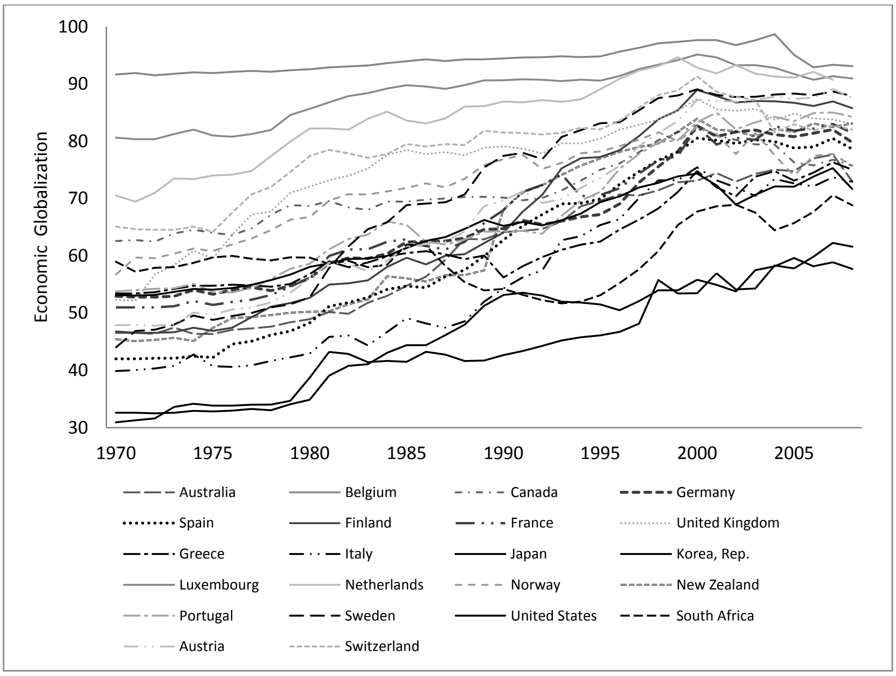
Notes: DFM-SV estimates of the instantaneous standard deviation of the innovations to the global and regional factors (endogenously determined), with standard deviation bands (dotted lines).

Figure 3.16: Standard deviation of idiosyncratic innovation and variance decomposition of global and regional factors



Notes: DFM-SV estimates of the evolution of the country-level factor model: the standard deviation of idiosyncratic innovation and the R^2 from the global factor, the regional factor, and the idiosyncratic term. Dotted lines are the 10 percent, 25 percent, 50 percent, 75 percent and 90 percent percentiles across countries, evaluated quarter by quarter.

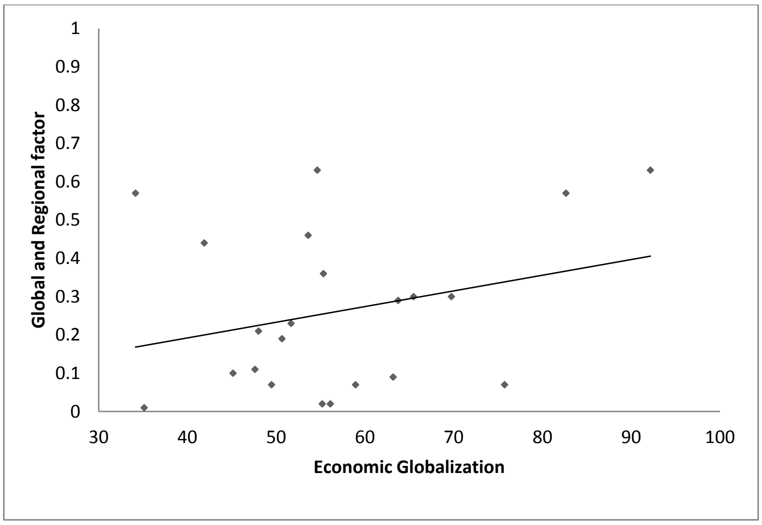
Figure 3.17: Economic globalization in OECD countries



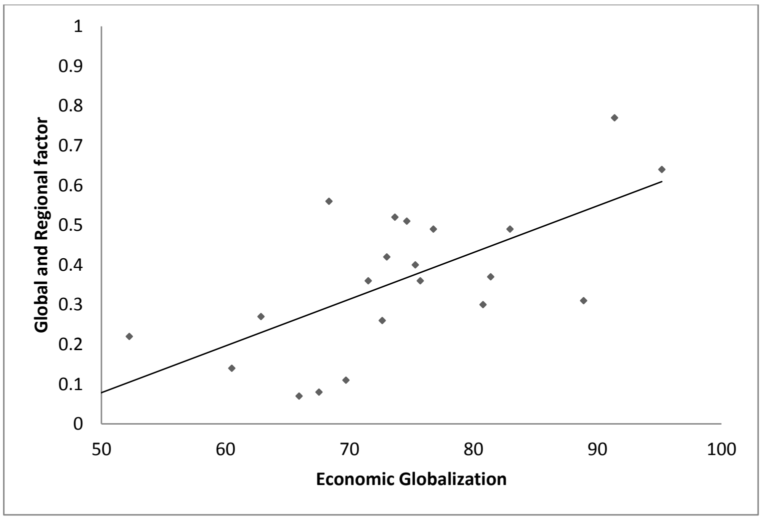
Notes: The measure of economic globalization is based on KOF Index of Globalization 2011.

Figure 3.18: Relationship between economic globalization and variance of inflation attributable to the global and regional factors

a. Over the Sample Period 1961-1982



b. Over the Sample Period 1983-2008



Notes: The measure of economic globalization is based on KOF Index of Globalization 2011 and variance decomposition of inflation attributable to the global and regional factors are from Table 3.5.

Appendices

Appendix A

Appendix to Chapter 3: Aggregate Inflation and Globalization

Table A.1: Maximum Likelihood estimates, restricted split sample estimation(exogenously determined regions - Composition 1)

Country	Region	λ	γ	ρ	$\sigma_{\varepsilon}(61-79)$	$\sigma_{\varepsilon}(80-08)$
New Zealand	1	0.98	-1.27	0.9	0.83	1.17
Korea	1	1.83	1.9	0.85	3.81	1.17
Japan	1	0.84	0.59	0.89	1.52	0.46
Australia	1	0.87	-1	0.88	0.94	0.72
Canada	1	0.93	-0.1	0.89	0.61	0.55
U.S.	1	1.25	0.44	0.97	0.49	0.38
South Africa	1	0.84	-0.47	0.94	1.39	1.21
Germany	2	0.58	0.67	0.93	0.41	0.38
Belgium	2	0.87	1.44	0.83	0.6	0.32
France	2	0.98	0.49	0.94	0.59	0.36
Luxembourg	2	0.81	1.62	0.84	0.48	0.35
Netherlands	2	0.56	0.53	0.92	1.06	0.39
Italy	2	1.04	0.59	0.97	1.24	0.51
Finland	3	0.97	-0.1	0.91	1.28	0.45
Switzerland	3	0.77	0	0.93	0.7	0.49
Sweden	3	1.27	-0.71	0.87	1.01	0.76
U.K.	3	1.46	-0.39	0.88	1.23	0.74
Norway	3	0.95	0.05	0.85	1.17	0.8
Austria	3	0.58	0.3	0.86	0.9	0.43
Greece	3	1.22	0.76	0.97	2.09	1.04
Portugal	3	0.65	1.97	0.94	3.38	1.22
Spain	3	0.77	1.94	0.91	1.74	0.18

Notes: Estimates are restricted split-sample MLEs of the Dynamic Factor Model with innovation variances that are constant over each sample but differ between samples. Regions are exogenously determined. The non-European countries are grouped together in Region 1, the European countries who were the founding members of the EMS(European Monetary Sysytem) make the Region 2 and the other European countries compriese Region 3. The sample period is splited into subsamples of 1961-1979 and 1980-2008 to examine the effect of EMS on the regional factor. λ is the factor loading on global factor, γ is factor loading on regional factor and ρ is autoregressive coefficient of disturbance term.

Table A.2: Variance decomposition of inflation based on unrestricted and restricted split sample estimation of the Dynamic Factor Model, 1961-1979 and 1980-2008 (exogenously determined regions - Composition 1)

Country	**Region**	**1961-1979**				**1980-2008**				**Decomposition of $(\mathbf{Var_{61-79}} - \mathbf{Var_{80-08}})/\mathbf{Var_{80-08}}$**			
		σ	R^2-F	R^2-R	R^2-e	σ	R^2-F	R^2-R	R^2-e	Total	F	R	e
New Zealand	1	1.99 1.98	0.23 0.15	0.05 0.21	0.72 0.64	2.54 2.50	0.07 0.08	0.40 0.13	0.54 0.79	0.62 0.60	-0.12 -0.03	0.59 -0.01	0.15 0.64
Korea	1	7.04 7.36	0.00 0.04	0.11 0.03	0.88 0.93	2.41 2.87	0.12 0.21	0.10 0.22	0.78 0.57	-0.88 -0.85	0.01 -0.01	-0.10 0.00	-0.79 -0.84
Japan	1	3.39 2.98	0.38 0.05	0.01 0.02	0.61 0.93	1.00 1.15	0.18 0.27	0.03 0.13	0.78 0.59	-0.91 -0.85	-0.37 -0.01	0.00 0.00	-0.54 -0.84
Australia	1	1.99 2.03	0.32 0.11	0.03 0.13	0.65 0.76	1.66 1.64	0.08 0.14	0.29 0.19	0.63 0.67	-0.31 -0.35	-0.26 -0.02	0.17 0.00	-0.22 -0.32
Canada	1	1.37 1.37	0.09 0.28	0.37 0.00	0.55 0.72	1.30 1.24	0.41 0.28	0.05 0.00	0.54 0.71	-0.1 -0.18	0.29 -0.05	-0.32 0.00	-0.06 -0.14
U.S.	1	1.37 1.41	0.28 0.48	0.46 0.05	0.25 0.47	1.09 1.21	0.65 0.54	0.04 0.07	0.31 0.39	-0.36 -0.27	0.13 -0.08	-0.44 0.00	-0.05 -0.18
South Africa	1	1.90 2.79	0.26 0.06	0.01 0.02	0.73 0.93	2.49 2.44	0.11 0.06	0.06 0.02	0.83 0.92	0.71 -0.24	-0.07 -0.01	0.09 0.00	0.69 -0.23
Germany	2	1.00 0.98	0.34 0.21	0.00 0.14	0.66 0.65	0.91 0.91	0.23 0.21	0.15 0.13	0.63 0.66	-0.16 -0.15	-0.15 -0.04	0.12 -0.03	-0.13 -0.09
Belgium	2	1.78 1.51	0.31 0.20	0.69 0.27	0.00 0.53	1.09 1.11	0.35 0.31	0.40 0.41	0.25 0.28	-0.62 -0.46	-0.18 -0.03	-0.53 -0.05	0.09 -0.38
France	2	1.38 1.40	0.39 0.30	0.04 0.04	0.58 0.66	0.91 1.02	0.31 0.47	0.09 0.06	0.61 0.48	-0.57 -0.47	-0.25 -0.05	0.00 -0.01	-0.31 -0.41
Luxembourg	2	1.40 1.41	0.26 0.20	0.16 0.40	0.59 0.40	1.19 1.19	0.25 0.24	0.52 0.46	0.23 0.30	-0.28 -0.29	-0.08 -0.03	0.22 -0.07	-0.42 -0.18
Netherlands	2	1.93 2.10	0.09 0.04	0.26 0.02	0.66 0.94	0.85 0.89	0.18 0.20	0.06 0.09	0.76 0.71	-0.81 -0.82	-0.05 -0.01	-0.25 0.00	-0.51 -0.81
Italy	2	2.66 2.60	0.34 0.10	0.05 0.02	0.60 0.89	0.95 1.29	0.10 0.33	0.14 0.05	0.76 0.62	-0.87 -0.75	-0.33 -0.02	-0.04 0.00	-0.5 -0.74
Finland	3	2.49 2.57	0.07 0.09	0.01 0.00	0.92 0.91	1.08 1.11	0.32 0.39	0.02 0.00	0.67 0.61	-0.81 -0.81	-0.01 -0.01	-0.01 0.00	-0.8 -0.8
Switzerland	3	1.63 1.48	0.37 0.16	0.05 0.00	0.58 0.84	1.08 1.09	0.42 0.25	0.01 0.00	0.57 0.75	-0.56 -0.45	-0.18 -0.03	-0.04 0.00	-0.34 -0.42
Sweden	3	1.91 2.14	0.14 0.22	0.06 0.00	0.81 0.78	1.67 1.73	0.24 0.28	0.08 0.05	0.69 0.67	-0.24 -0.35	0.04 -0.04	0.00 0.03	-0.29 -0.35
U.K.	3	2.70 2.58	0.27 0.20	0.02 0.00	0.71 0.80	1.40 1.74	0.29 0.35	0.00 0.02	0.71 0.63	-0.73 -0.54	-0.19 -0.03	-0.02 0.01	-0.52 -0.52
Norway	3	2.24 2.30	0.06 0.10	0.35 0.00	0.59 0.90	1.60 1.64	0.27 0.17	0.02 0.00	0.71 0.83	-0.49 -0.5	0.08 -0.02	-0.34 0.00	-0.23 -0.48
Austria	3	1.65 1.74	0.08 0.07	0.20 0.00	0.72 0.93	0.96 0.91	0.32 0.20	0.09 0.03	0.60 0.76	-0.66 -0.73	0.03 -0.01	-0.17 0.01	-0.52 -0.72
Greece	3	3.99 4.23	0.16 0.05	0.14 0.00	0.71 0.95	2.07 2.26	0.08 0.15	0.04 0.03	0.88 0.82	-0.73 -0.71	-0.13 -0.01	-0.13 0.01	-0.47 -0.72
Portugal	3	5.41 6.60	0.11 0.01	0.07 0.00	0.83 0.99	2.68 2.65	0.00 0.03	0.26 0.17	0.73 0.80	-0.75 -0.84	-0.11 0.00	0.00 0.03	-0.65 -0.86
Spain	3	3.30 3.37	0.07 0.03	0.06 0.00	0.87 0.97	1.20 1.25	0.10 0.19	0.47 0.73	0.43 0.08	-0.87 -0.86	-0.06 -0.01	0.00 0.10	-0.81 -0.96
Mean		2.48 2.59	0.21 0.14	0.14 0.06	0.65 0.80	1.46 1.54	0.23 0.24	0.15 0.14	0.62 0.62	-0.47 -0.49	-0.09 -0.02	-0.05 0.00	-0.33 -0.47
Percentiles													
0.1		1.37 1.40	0.07 0.04	0.01 0.00	0.55 0.53	0.91 0.91	0.08 0.08	0.02 0.00	0.31 0.30	-0.87 -0.85	-0.26 -0.05	-0.34 -0.03	-0.79 -0.84
0.25		1.63 1.48	0.09 0.05	0.03 0.00	0.59 0.66	1.00 1.11	0.10 0.17	0.04 0.02	0.54 0.57	-0.81 -0.81	-0.18 -0.03	-0.17 0.00	-0.52 -0.8
0.5		1.93 2.10	0.23 0.10	0.06 0.02	0.66 0.84	1.19 1.24	0.23 0.21	0.08 0.06	0.63 0.66	-0.62 -0.5	-0.11 -0.02	-0.02 0.00	-0.42 -0.48
0.75		2.70 2.79	0.32 0.20	0.20 0.05	0.73 0.93	1.67 1.74	0.32 0.31	0.26 0.17	0.76 0.76	-0.28 -0.29	0.01 -0.01	0.00 0.01	-0.13 -0.23
0.9		3.99 4.23	0.37 0.28	0.37 0.21	0.87 0.95	2.49 2.50	0.41 0.39	0.40 0.41	0.78 0.82	-0.1 -0.18	0.08 -0.01	0.17 0.03	0.09 -0.14

Notes: the first entry in each cell is computed using the unrestricted split sample estimates of the Dynamic Factor Model; the second entry is computed using restricted split sample estimates for which the factor loadings and idiosyncratic autoregressive coefficients are restricted to equal their full sample values. The first numeric column is the region of the country. The next block of the columns contains the standard deviation of inflation over 1961-1979(Pre- EMS period) and the fraction of the variance attributed to global factor F, the regional factor R, and the idiosyncratic disturbance e. the second block contains the same statistics for 1980-2008(Post EMS period). The last block decomposes the relative change in the variance from the first to the second period. The first column in the last block is the Total of last three columns.

Table A.3: Maximum Likelihood estimates, restricted split sample estimation(exogenously determined regions - Composition 2)

Country	Region	λ	γ	ρ	$\sigma_\varepsilon(61-99)$	$\sigma_\varepsilon(00-08)$
New Zealand	1	1.49	1.37	0.91	1.14	0.31
Korea	1	1.46	-1.77	0.77	2.81	0.82
Japan	1	0.88	-0.62	0.9	1.1	0.36
Australia	1	1.16	1	0.84	0.81	0.66
Canada	1	0.99	0.04	0.9	0.58	0.51
U.S.	1	1.21	-0.56	0.98	0.42	0.34
South Africa	1	0.93	0.55	0.93	1.22	1.42
Germany	2	0.63	0.44	0.93	0.44	0.26
Belgium	2	0.98	1.78	0.8	0.35	0.37
France	2	1.01	0.46	0.93	0.5	0.21
Luxembourg	2	0.84	1.37	0.85	0.5	0.37
Netherlands	2	0.55	1.22	0.9	0.74	0.34
Italy	2	0.64	1.4	0.98	0.96	0.16
Finland	2	0.97	0.17	0.92	0.95	0.33
Austria	2	0.69	0.65	0.79	0.69	0.27
Portugal	2	0.63	0.97	0.96	2.61	0.37
Spain	2	1.18	0.01	0.89	1.29	0.36
Greece	2	1.13	-0.85	0.96	1.65	0.39
Sweden	3	0.98	1.61	0.83	1	0.01
U.K.	3	1.07	0.48	0.92	1.09	0.35
Norway	3	0.95	1.08	0.81	1	0.76
Switzerland	3	0.97	0.1	0.96	0.61	0.24

Notes: Estimates are restricted split-sample MLEs of the Dynamic Factor Model with innovation variances that are constant over each sample but differ between samples using another composition of exogenously determined regions. The non-European countries are grouped together in Region 1 as in composition 1, the second region contains early member countries of Euro(All countries in the group joined the Euro in 1999 apart from Greece who became the member in 2000) and the rest of European countries compriese Region 3. The sample period is splited into subsamples of 1961-1999 and 2000-2008 to examine the effect of the Euro on the regional factor. λ is the factor loading on global factor, γ is factor loading on regional factor and ρ is autoregressive coefficient of disturbance term.

Table A.4: Variance decomposition of inflation based on unrestricted and restricted split sample estimation of the Dynamic Factor Model, 1961-1999 and 2000-2008 (exogenously determined regions - Composition 2)

Country	**Region**	**1961-1999**				**2000-2008**				**Decomposition of $(\mathbf{Var}_{61-99} - \mathbf{Var}_{00-08})/\mathbf{Var}_{00-08}$**			
		σ	R^2-F	R^2-R	R^2-e	σ	R^2-F	R^2-R	R^2-e	Total	F	R	e
New Zealand	1	2.57 2.69	0.10 0.17	0.10 0.18	0.80 0.65	1.11 1.13	0.78 0.69	0.03 0.03	0.18 0.28	-0.81 -0.83	0.05 -0.05	-0.1 -0.18	-0.76 -0.6
Korea	1	5.52 5.33	0.06 0.04	0.12 0.08	0.82 0.88	1.11 1.74	0.26 0.28	0.02 0.02	0.73 0.70	-0.96 -0.89	-0.05 -0.01	-0.12 -0.07	-0.79 -0.81
Japan	1	2.37 2.25	0.25 0.08	0.02 0.05	0.73 0.86	0.69 0.89	0.04 0.39	0.42 0.01	0.54 0.60	-0.92 -0.84	-0.24 -0.02	0.01 -0.05	-0.69 -0.77
Australia	1	1.85 1.91	0.18 0.20	0.17 0.19	0.65 0.61	1.30 1.43	0.38 0.26	0.25 0.01	0.37 0.73	-0.51 -0.44	0.00 -0.06	-0.04 -0.19	-0.47 -0.2
Canada	1	1.32 1.32	0.24 0.31	0.02 0.00	0.74 0.69	1.30 1.15	0.61 0.30	0.01 0.00	0.39 0.70	-0.04 -0.25	0.34 -0.08	-0.01 0.00	-0.37 -0.16
U.S.	1	1.30 1.31	0.42 0.46	0.20 0.13	0.38 0.41	1.12 1.02	0.83 0.55	0.00 0.01	0.17 0.44	-0.26 -0.4	0.19 -0.13	-0.2 -0.13	-0.25 -0.14
South Africa	1	2.53 2.50	0.05 0.07	0.01 0.03	0.94 0.89	2.83 2.81	0.18 0.04	0.19 0.00	0.63 0.96	0.25 0.26	0.18 -0.02	0.23 -0.03	-0.16 0.32
Germany	2	0.97 1.00	0.20 0.22	0.07 0.06	0.72 0.73	0.67 0.65	0.58 0.36	0.02 0.04	0.40 0.60	-0.52 -0.57	0.07 -0.06	-0.07 -0.04	-0.53 -0.47
Belgium	2	1.35 1.38	0.29 0.27	0.36 0.51	0.35 0.22	1.29 1.05	0.35 0.34	0.27 0.24	0.38 0.42	-0.09 -0.42	0.04 -0.08	-0.12 -0.37	-0.01 0.02
France	2	1.26 1.25	0.40 0.35	0.05 0.04	0.54 0.60	0.72 0.76	0.72 0.69	0.01 0.03	0.27 0.28	-0.67 -0.63	-0.16 -0.1	-0.05 -0.03	-0.45 -0.5
Luxembourg	2	1.31 1.35	0.23 0.21	0.19 0.32	0.59 0.47	1.01 0.95	0.35 0.31	0.35 0.17	0.29 0.52	-0.4 -0.5	-0.02 -0.06	0.02 -0.23	-0.41 -0.21
Netherlands	2	1.54 1.61	0.09 0.06	0.25 0.18	0.66 0.76	0.80 0.82	0.14 0.18	0.29 0.19	0.58 0.64	-0.73 -0.74	-0.05 -0.02	-0.17 -0.13	-0.51 -0.59
Italy	2	2.11 2.10	0.22 0.05	0.11 0.14	0.67 0.81	0.65 0.65	0.21 0.38	0.79 0.39	0.00 0.23	-0.91 -0.91	-0.2 -0.01	-0.04 -0.1	-0.67 -0.79
Finland	2	1.96 1.97	0.16 0.13	0.00 0.00	0.84 0.87	0.80 0.88	0.29 0.48	0.01 0.00	0.70 0.52	-0.83 -0.8	-0.12 -0.04	0.00 0.00	-0.72 -0.76
Austria	2	1.30 1.39	0.13 0.13	0.13 0.07	0.74 0.80	0.75 0.68	0.54 0.40	0.00 0.08	0.46 0.53	-0.67 -0.76	0.05 -0.04	-0.13 -0.05	-0.59 -0.67
Portugal	2	4.83 5.15	0.09 0.01	0.00 0.01	0.91 0.98	0.72 0.87	0.19 0.21	0.30 0.10	0.51 0.69	-0.98 -0.97	-0.09 0.00	0.01 -0.01	-0.89 -0.96
Spain	2	2.51 2.59	0.06 0.11	0.00 0.00	0.94 0.89	0.95 1.01	0.86 0.54	0.02 0.00	0.12 0.46	-0.86 -0.85	0.07 -0.03	0.00 0.00	-0.92 -0.82
Greece	2	3.43 3.37	0.14 0.06	0.19 0.02	0.67 0.92	0.77 1.06	0.62 0.44	0.02 0.05	0.36 0.51	-0.95 -0.9	-0.11 -0.02	-0.19 -0.01	-0.65 -0.87
Sweden	3	1.97 1.98	0.14 0.13	0.08 0.00	0.78 0.87	0.99 1.01	0.38 0.36	0.62 0.64	0.00 0.00	-0.75 -0.74	-0.04 -0.04	0.08 0.17	-0.78 -0.87
U.K.	3	2.30 2.23	0.26 0.12	0.00 0.00	0.74 0.88	0.80 0.98	0.22 0.46	0.05 0.06	0.74 0.47	-0.88 -0.81	-0.23 -0.03	0.00 0.01	-0.65 -0.78
Norway	3	1.92 1.94	0.05 0.13	0.22 0.00	0.72 0.87	1.74 1.60	0.61 0.14	0.05 0.12	0.34 0.75	-0.18 -0.32	0.44 -0.04	-0.18 0.08	-0.45 -0.36
Switzerland	3	1.36 1.40	0.23 0.26	0.00 0.00	0.76 0.74	0.86 0.77	0.85 0.62	0.00 0.00	0.15 0.38	-0.6 -0.7	0.11 -0.07	0.00 0.00	-0.71 -0.63
Mean		2.16 2.18	0.18 0.16	0.10 0.09	0.71 0.75	1.04 1.09	0.45 0.38	0.17 0.10	0.38 0.52	-0.6 -0.64	0.01 -0.05	-0.05 -0.06	-0.56 -0.53
Percentiles													
0.1		1.30 1.31	0.06 0.05	0.00 0.00	0.54 0.47	0.69 0.68	0.18 0.18	0.00 0.00	0.12 0.28	-0.95 -0.9	-0.2 -0.08	-0.18 -0.19	-0.79 -0.87
0.25		1.32 1.38	0.09 0.07	0.01 0.00	0.66 0.65	0.75 0.82	0.22 0.28	0.01 0.01	0.18 0.42	-0.88 -0.84	-0.11 -0.06	-0.12 -0.13	-0.72 -0.79
0.5		1.92 1.94	0.16 0.13	0.08 0.04	0.73 0.80	0.86 0.98	0.38 0.36	0.03 0.03	0.37 0.52	-0.73 -0.74	-0.02 -0.04	-0.04 -0.04	-0.65 -0.63
0.75		2.51 2.50	0.24 0.22	0.19 0.14	0.80 0.88	1.12 1.13	0.62 0.48	0.29 0.12	0.54 0.69	-0.4 -0.44	0.07 -0.02	0.00 0.00	-0.45 -0.21
0.9		3.43 3.37	0.29 0.31	0.22 0.19	0.91 0.89	1.30 1.60	0.83 0.62	0.42 0.24	0.70 0.73	-0.09 -0.32	0.19 -0.01	0.02 0.01	-0.25 -0.14

Notes: the first entry in each cell is computed using the unrestricted split sample estimates of the Dynamic Factor Model; the second entry is computed using restricted split sample estimates for which the factor loadings and idiosyncratic autoregressive coefficients are restricted to equal their full sample values. The first numeric column is the region of the country. The next block of the columns contains the standard deviation of inflation over 1961-1999(Pre- Euro period) and the fraction of the variance attributed to global factor F, the regional factor R, and the idiosyncratic disturbance e. the second block contains the same statistics for 2000-2008(Post Euro period). The last block decomposes the relative change in the variance from the first to the second period. The first column in the last block is the Total of last three columns.

Table A.5: Maximum Likelihood estimates, restricted split sample estimation(exogenously determined regions - Composition 3)

Country	**Region**	$\boldsymbol{\lambda}$	$\boldsymbol{\gamma}$	$\boldsymbol{\rho}$	$\boldsymbol{\sigma_\varepsilon(61-99)}$	$\boldsymbol{\sigma_\varepsilon(00-08)}$
New Zealand	1	1.48	1.36	0.9	1.15	0.32
Korea	1	1.43	-1.69	0.77	2.83	0.81
Japan	1	0.92	-0.69	0.88	1.09	0.36
Australia	1	1.16	1.07	0.83	0.81	0.66
Canada	1	0.98	0.02	0.91	0.59	0.51
U.S.	1	1.18	-0.58	0.98	0.44	0.33
South Africa	1	0.91	0.58	0.94	1.22	1.42
Germany	2	0.65	0.3	0.94	0.44	0.26
Belgium	2	1.03	1.67	0.83	0.33	0.31
France	2	1.01	0.35	0.93	0.5	0.21
Luxembourg	2	0.87	1.2	0.86	0.5	0.34
Netherlands	2	0.62	0.85	0.89	0.75	0.36
Italy	2	0.67	0.91	0.98	0.97	0.17
Finland	3	0.97	0.37	0.9	0.95	0.32
Norway	3	0.86	1.27	0.81	0.92	0.74
Sweden	3	0.93	1.12	0.84	0.94	0.28
Austria	4	0.7	0.33	0.8	0.71	0.26
Portugal	4	0.68	0.25	0.96	2.61	0.39
Spain	4	1.16	-0.92	0.85	1.25	0.35
Greece	4	1.04	1.16	0.97	1.68	0.39
Switzerland	4	1.03	1.87	0.83	0.19	0.23
U.K.	4	1.14	-0.35	0.89	1.07	0.38

Notes: Estimates are restricted split-sample MLEs of the Dynamic Factor Model with innovation variances that are constant over each sample but differ between samples using another composition of exogenously determined regions. The non-European countries are grouped together in Region 1 as earlier, the second region contains BENELUX states(Belgium, Netherlands and Luxembourg), Germany, France and Italy, the third region includes scandinavian countries and the rest of European countries in our sample comprise Region 4. The sample period is splited into subsamples of 1961-1999 and 2000-2008. λ is the factor loading on global factor, γ is factor loading on regional factor and ρ is autoregressive coefficient of disturbance term.

Table A.6: Variance decomposition of inflation based on unrestricted and restricted split sample estimation of the Dynamic Factor Model, 1961-1999 and 2000-2008 (exogenously determined regions - Composition 3)

Country	**Region**	**1961-1999**				**2000-2008**				**Decomposition of** $(\mathbf{Var_{61-99}} - \mathbf{Var_{00-08}})/\mathbf{Var_{00-08}}$			
		σ	R^2-F	R^2-R	R^2-e	σ	R^2-F	R^2-R	R^2-e	Total	F	R	e
New Zealand	1	2.59 2.69	0.09 0.17	0.01 0.16	0.89 0.67	1.09 1.12	0.77 0.68	0.04 0.03	0.19 0.29	-0.82 -0.83	0.04 -0.05	-0.01 -0.16	-0.86 -0.62
Korea	1	5.45 5.32	0.03 0.04	0.10 0.07	0.87 0.90	1.11 1.72	0.28 0.27	0.01 0.02	0.71 0.71	-0.96 -0.9	-0.02 -0.01	-0.1 -0.06	-0.84 -0.82
Japan	1	2.33 2.23	0.23 0.09	0.02 0.06	0.76 0.84	0.69 0.89	0.06 0.42	0.33 0.01	0.62 0.57	-0.91 -0.84	-0.22 -0.03	0.01 -0.06	-0.7 -0.75
Australia	1	1.90 1.92	0.16 0.20	0.03 0.20	0.81 0.60	1.29 1.42	0.37 0.26	0.26 0.01	0.36 0.73	-0.54 -0.45	0.01 -0.06	0.10 -0.19	-0.65 -0.2
Canada	1	1.33 1.34	0.17 0.29	0.05 0.00	0.78 0.71	1.30 1.14	0.59 0.28	0.01 0.00	0.40 0.72	-0.04 -0.27	0.40 -0.09	-0.04 0.00	-0.39 -0.18
U.S.	1	1.32 1.32	0.34 0.44	0.66 0.12	0.00 0.44	1.10 1.00	0.81 0.55	0.00 0.01	0.19 0.44	-0.31 -0.44	0.21 -0.13	-0.66 -0.12	0.13 -0.19
South Africa	1	2.55 2.51	0.04 0.07	0.00 0.03	0.96 0.89	2.82 2.82	0.19 0.04	0.16 0.00	0.64 0.96	0.23 0.26	0.20 -0.02	0.20 -0.03	-0.17 0.31
Germany	2	0.97 0.99	0.26 0.24	0.01 0.03	0.72 0.73	0.67 0.66	0.57 0.38	0.00 0.04	0.43 0.58	-0.52 -0.56	0.01 -0.07	-0.01 -0.01	-0.52 -0.48
Belgium	2	1.39 1.38	0.31 0.31	0.58 0.50	0.11 0.19	1.28 1.14	0.43 0.32	0.39 0.43	0.18 0.26	-0.15 -0.31	0.06 -0.09	-0.25 -0.2	0.05 -0.02
France	2	1.26 1.24	0.43 0.36	0.03 0.03	0.54 0.61	0.71 0.76	0.72 0.69	0.01 0.04	0.28 0.27	-0.68 -0.63	-0.2 -0.11	-0.02 -0.01	-0.46 -0.51
Luxembourg	2	1.31 1.34	0.27 0.23	0.12 0.27	0.62 0.49	0.99 1.00	0.36 0.30	0.48 0.29	0.16 0.41	-0.42 -0.44	-0.06 -0.07	0.16 -0.11	-0.52 -0.26
Netherlands	2	1.56 1.57	0.11 0.09	0.14 0.10	0.74 0.81	0.83 0.87	0.14 0.20	0.17 0.19	0.68 0.61	-0.72 -0.69	-0.07 -0.03	-0.1 -0.04	-0.55 -0.63
Italy	2	2.11 2.05	0.29 0.06	0.04 0.07	0.67 0.88	0.62 0.67	0.33 0.39	0.47 0.37	0.20 0.25	-0.91 -0.89	-0.26 -0.02	0.00 -0.03	-0.65 -0.85
Finland	3	1.95 1.95	0.14 0.14	0.06 0.01	0.81 0.85	0.80 0.89	0.32 0.47	0.05 0.05	0.64 0.49	-0.83 -0.79	-0.09 -0.04	-0.05 0.00	-0.7 -0.75
Norway	3	1.92 1.94	0.05 0.11	0.22 0.15	0.73 0.74	1.70 1.58	0.58 0.11	0.05 0.16	0.36 0.72	-0.22 -0.34	0.41 -0.03	-0.18 -0.04	-0.44 -0.26
Sweden	3	1.99 1.99	0.13 0.12	0.10 0.11	0.77 0.77	0.99 0.96	0.40 0.37	0.60 0.35	0.00 0.29	-0.75 -0.77	-0.03 -0.04	0.04 -0.03	-0.77 -0.7
Austria	4	1.32 1.40	0.18 0.14	0.02 0.02	0.81 0.84	0.74 0.65	0.54 0.45	0.00 0.00	0.46 0.55	-0.69 -0.78	-0.01 -0.04	-0.02 -0.02	-0.67 -0.72
Portugal	4	4.89 5.14	0.08 0.01	0.00 0.00	0.92 0.99	0.78 0.87	0.22 0.24	0.34 0.00	0.44 0.76	-0.97 -0.97	-0.07 0.00	0.01 0.00	-0.91 -0.97
Spain	4	2.48 2.53	0.10 0.11	0.06 0.05	0.85 0.83	1.00 0.97	0.89 0.55	0.06 0.00	0.06 0.45	-0.84 -0.85	0.05 -0.03	-0.05 -0.05	-0.84 -0.77
Greece	4	3.46 3.47	0.07 0.05	0.05 0.04	0.88 0.91	0.74 1.00	0.57 0.42	0.00 0.00	0.43 0.58	-0.95 -0.92	-0.04 -0.01	-0.05 -0.04	-0.86 -0.86
Switzerland	4	1.39 1.43	0.26 0.28	0.63 0.66	0.11 0.06	0.86 0.77	0.87 0.69	0.00 0.00	0.12 0.31	-0.62 -0.71	0.08 -0.08	-0.63 -0.66	-0.06 0.03
U.K.	4	2.27 2.20	0.28 0.15	0.01 0.01	0.72 0.84	0.78 1.01	0.31 0.49	0.39 0.00	0.30 0.51	-0.88 -0.79	-0.24 -0.04	0.04 -0.01	-0.68 -0.74
Mean		2.17 2.18	0.18 0.17	0.13 0.12	0.68 0.71	1.04 1.09	0.47 0.39	0.17 0.09	0.36 0.52	-0.61 -0.63	0.01 -0.05	-0.07 -0.09	-0.55 -0.5
Percentiles													
0.1		1.31 1.32	0.05 0.05	0.01 0.01	0.11 0.44	0.69 0.67	0.19 0.20	0.00 0.00	0.12 0.27	-0.95 -0.9	-0.22 -0.09	-0.25 -0.19	-0.86 -0.85
0.25		1.33 1.38	0.09 0.09	0.02 0.03	0.67 0.61	0.74 0.87	0.31 0.27	0.01 0.00	0.19 0.31	-0.88 -0.84	-0.07 -0.07	-0.1 -0.11	-0.77 -0.75
0.5		1.92 1.94	0.16 0.14	0.05 0.06	0.76 0.77	0.86 0.97	0.40 0.38	0.05 0.01	0.36 0.51	-0.72 -0.77	-0.02 -0.04	-0.02 -0.04	-0.65 -0.63
0.75		2.48 2.51	0.27 0.24	0.12 0.15	0.85 0.85	1.11 1.14	0.59 0.49	0.34 0.16	0.46 0.71	-0.42 -0.44	0.06 -0.03	0.01 -0.01	-0.44 -0.2
0.9		3.46 3.47	0.31 0.31	0.58 0.27	0.89 0.90	1.30 1.58	0.81 0.68	0.47 0.35	0.64 0.73	-0.15 -0.31	0.21 -0.01	0.10 0.00	-0.06 -0.02

Notes: the first entry in each cell is computed using the unrestricted split sample estimates of the Dynamic Factor Model; the second entry is computed using restricted split sample estimates for which the factor loadings and idiosyncratic autoregressive coefficients are restricted to equal their full sample values. The first numeric column is the region of the country. The next block of the columns contains the standard deviation of inflation over 1961-1999(Pre- Euro period) and the fraction of the variance attributed to global factor F, the regional factor R, and the idiosyncratic disturbance e. the second block contains the same statistics for 2000-2008(Post Euro period). The last block decomposes the relative change in the variance from the first to the second period. The first column in the last block is the Total of last three columns.

Chapter 4

Does Disaggregation Matter for Inflation Globalization?

4.1 Introduction

Central Banks are preoccupied by global integration of markets and the implications of this for the conduct and effectiveness of monetary policy. As emphasized by Bernanke (2007),

"*The integration of rapidly industrial economies into the global trading system clearly has had important effects on the prices of both manufacturers and commodities, reinforcing the need to monitor international influences on the inflation process.*"

The operations of monetary policy may have been mainly affected by globalization through its influence on the inflation process. The inflation process in turn is affected by international factors through several channels. The effect of international factors on domestic inflation through lower import prices and increased competitive pressures (by increasing productivity growth, reduced costs and reduced mark ups) is emphasized by Bernanke (2007). These channels are extensively examined by researchers using empirical and theoretical models. In chapter 2 where we reviewed the literature, it is extensively discussed how globalization may affect the inflation process through these channels.[1]

A new strand of literature on globalisation of inflation is developed recently which is a counterpart of the literature on international synchronisation of business cycles. This strand of literature attempt to measure the co-movements in national inflation rates across countries. Ciccarelli and Mojon (2010) highlight that inflation has become a global phenomenon and almost 70 percent of the variance of national inflation of OECD countries during 1961-2007 is explained by a single common factor. Mumtaz and Surico (2012), Neely and Rapach (2011), Bagliano and Morana (2009) and Monacelli and Sala (2009) estimate the global common factor in national inflation rates across a large group of countries. They find that a significant amount of variation in inflation across countries is explained by a common global factor. We also estimated a global factor and regional factors in aggregate inflation series of 22 OECD countries in Chapter 3 and find that global factor gains importance over time in explaining the movements of inflation. Monacelli and Sala (2009) report a positive and significant relationship between the estimated common factor and trade intensity.

A number of studies that address the theme of inflation and globalisation by estimating the co-movements of inflation across countries examine aggregate inflation.[2] An investigation of globalization of sectoral inflation may complement and deepen our understanding of globalization of inflation. Since aggregate inflation may mask some of the sectoral inflation dynamics and in particular, extent of globalization differs across sectors.

Thus, we argue that estimating a single global common factor from disaggregated

[1] The empirical evidence is provided by a number of authors. For instance, Koske et al. (2010) estimate the direct impact of import prices from non-OECD on OECD import price inflation. They find that the contribution of import prices in driving up the consumer prices has become increasingly important since the mid 1990s. Gamber and Hung (2001) conduct the analysis for United States over a period of 1987-92 and show that domestic prices in particular sectoral categories were sensitive to prices of imports in the same categories and sensitivity was greater in the sectors which were faced with greater import penetration. Kamin et al. (2006), IMF (2006), Ihrig et al. (2007) and Guilloux and Kharroubi (2008) report a small impact of import prices on inflation. IMF (2006) and Chen et al. (2004) find empirical support for the effect of competitive pressures on inflation.

[2] Monacelli and Sala (2009) is an exception. They investigate disaggregated inflation for the United States, the United Kingdom, France and Germany over a period 1991-2004. They estimate a single common factor and relate the estimated commonality ratio to trade intensity.

inflation data (an approach used by Monacelli and Sala (2009)) may not capture true nature and size of global factor because the extent of globalization across sectors differs and a global shock may not affect all the sectors of an economy with similar intensity. For example a global shock affecting the prices in agriculture sector may not affect the prices in health and social work sector in same way. Hence, it is important to capture a global and a sector specific common factor at the level of disaggregate data. Intuitively, the sector specific factor in the sectors that are more open to trade must be higher than the sectors which are less exposed to international trade.

This Chapter provides analysis of international co-movements of inflation at disaggregated level. We contribute to the literature, first, by analysing disaggregate sectoral inflation and consider a larger sample of countries over an extended period of 1971-2007. Secondly, we decompose the sectoral inflation into a common factor (henceforth a global factor), sector specific factors and idiosyncratic component using a Dynamic Factor Model. The global common factor captures the effect of a global shock on all sectors of all countries and the sector specific factors capture the effects of shocks that affect particular sectors in all countries. This allows us to examine the co-movements in tradable and non-tradable sectors across countries. We expect that the inflation in tradable sectors across countries should display higher co-movements than non-tradable sectors if increased integration of world's factor and product markets is one of the responsible factors in globalisation of inflation. Once we find that sector specific factors are important, we estimate a single dynamic factor model for individual panel of sectors across all countries (separately) as robustness check. To reconcile our analysis with Monacelli and Sala (2009), we estimate a single factor model for all sectors across all countries. Finally, we investigate the relationship between the sector specific factor and sectoral trade openness. We use import penetration and share of imports and exports in sectoral output as measures of trade openness.

The rest of the Chapter is set out as follows. Section 4.2 reviews the related literature. Section 4.3 explains our data set and preliminary analysis. Section 4.4 outlines the econometric methodology, while the empirical results are presented and discussed in section 4.5. In section 4.6 we examine the relationship between trade openness and the common factor in sectors across the countries. Section 4.7 concludes and summarises our findings.

4.2 A Brief Review of Literature

There is a strong nexus between inflation across countries and global integration. The link of globalisation to inflation works through various channels that include low import prices and increased competitive pressures. The impact of increased global integration on inflation is mainly investigated by using two different approaches. First, a Philips Curve frame work with different specifications of the process driving inflation is used. However, this does not provide conclusive evidence on the effect of globalisation on inflation dynamics.[3]

The literature that attempt to find relationship between globalization and inflation use both aggregate and sectoral data on inflation. IMF (2006) considers a sectoral perspective on globalization and inflation. They note that the sectors that are more exposed to foreign trade face more competitive pressures. Consequently, increased competition increases the price elasticity of demand, forces producers to lower margins and decrease prices. Hence, the sectors that are more exposed to foreign competition must experience smaller increase in prices than other sectors which have less exposure to foreign competition. They show that the relative prices in the sectors (which are open to trade) were negatively correlated to measure of globalization (import to production ratio). Similar results are documented by Chen et al. (2004) who state that increased openness reduces mark-ups and increase productivity. They show that in the European manufacturing sector, increased imports decreased prices by 2.3 percent, mark-ups by 1.6 percent and increased productivity by 11 percent. Similar findings based on sectoral inflation data are reported by Gamber and Hung (2001), Koske et al. (2010) and Binici et al. (2012). It suggests that the empirical evidence of the effect of globalization on inflation through increased global competition is more convincing at sectoral level.

[3]The pronounced evidence favouring the positive impact of globalisation on inflation is provided by Borio and Filardo (2007) among others which is however challenged by Ihrig et al. (2007) who show that Borio and Filardos results are not robust to alternate measures of foreign output gap.

Second, a recently developed alternative approach to quantify the global effects on the domestic inflation process is to measure the co-movements of inflation rates across countries. Dynamic factor models are used to measure the co-movements of macroeconomic variables by decomposing them into common and idiosyncratic components.[4] The dynamic factor model presumes that the observed co-movements in a large set of time series is due to a small number of unobserved common dynamic factor. Thus this approach identifies a common factor that drives co-movements in inflation rates across countries.

A static factor model is used by Ciccarelli and Mojon (2010) to examine global inflation. They point out that aggregate inflation in 22 OECD countries is a global phenomenon as 70 percent of the inflation variability in these countries can be explained by a single common factor. Neely and Rapach (2011) decompose the aggregate inflation rates of 65 countries into an international, regional and idiosyncratic components. They find that on average 34 percent of the inflation variability is explained by the international factor while the regional and idiosyncratic factors account for 16 percent and 50 percent of inflation variability respectively. We apply a Dynamic Factor Model with Stochastic Volatility (DFM-SV) to decompose the inflation of 22 OECD countries into a global, regional and an idiosyncratic component in Chapter 3 of this thesis. We find that though the country specific factors are important drivers of inflation dynamics, the importance of the global factor is increasing over time at the expense of idiosyncratic component.

The above cited studies examine aggregate inflation data to investigate the role of international factor in inflation dynamics. Monacelli and Sala (2009) contribute to the literature on global inflation by looking at highly disaggregated monthly product-category[5] inflation data of four industrialized countries to address the issue. They apply a factor model to a cross section of 948 consumer prices and conclude that one international common factor explains, on average, 15 percent to 30 percent of variance of consumer product inflation rates.[6] Mumtaz and Surico (2012) examine the role of

[4]For instance, this approach is applied to estimate the synchronization of business cycles by Kose et al. (2003), and Aiolfi et al. (2010) among many others.

[5]By product category, they mean that the data is less aggregated than individual scanner data and higher than sector price data.

[6]This range depends on the type of transformation applied to the data. 15 percent is for the data transformed by

common and idiosyncratic factors in the evolution of disaggregated inflation dynamics in 13 countries over a period of 1961-2004. They apply a dynamic factor model with stochastic volatility and conclude that the reduction in persistence, volatility and level of inflation coincide with the substantial increase in international co-movements of inflation in past two decades. However, the high volatility of inflation in the seventies was due to country specific factors.

The increased importance of global common factor in explaining the variations of inflation across countries may be attributed to increased integration of factor and product markets. Monacelli and Sala (2009) test this hypothesis by examining relationship between sectoral trade intensity and sectoral commonality ratio.[7] They find a positive and significant relationship between trade intensity and commonality ratio.

To summarise, the empirical literature, addressing the general theme of globalisation and inflation provides supporting evidence that international factors are important in the dynamics of inflation process. However, the literature on global inflation, in particular at sectoral level is limited.

4.3 Data and Preliminary Analysis

We computed inflation rate from the annual data on the Gross Value Added price index from the EUKLEMS database for 15 sectors[8] of 15 OECD countries: Austria, Belgium, Finland, France, Germany, Greece, Italy, Korea, Luxembourg, Netherlands, Portugal, Spain, Sweden, the United Kingdom and the United States. Thus in total, we have 225 annual series of sectoral inflation. The EUKLEMS is the database which is built with the objective of developing a system of analysis at industry level. It provides internationally harmonized and national accounts based high quality data on prices, output and labour compensations. The sample period under investigation is 1971-2007.

month-on-month log changes and 30 percent for year-on year log changes.

[7] Their measure of commonality ratio is computed at the level of product category and the data on sectoral trade intensity is available at more aggregate level. Therefore, they map the product category and sectoral classification and then take the average of commonality ratio estimated by product category inflation data to match it with sectoral trade intensity data.

[8] See Table 4.1 for classification of sectors.

The sectoral inflation rates across sample countries are plotted in Figure 4.1 and the changes in inflation rates are shown in Figure 4.2. In Figure 4.2 dotted lines are first differenced sectoral inflation rates for 15 OECD countries and the median, 25 and 75 percentiles are in solid lines. The Plots in Figure 4.1 and Figure 4.2 depict that the sectoral inflation is highly volatile and less persistent. However, volatility in many sectors decreases since the early 1990s. These are the features especially associated with disaggregated data. The noteworthy point in the plots is that the sectoral inflation across countries appears to co-move throughout the sample period. These co-movements are strikingly high in some sectors. For example, inflation in agriculture, hunting, forestry and fishing, mining and quarrying, education, total manufacturing sectors, electricity, gas, water supply and transport storage and communication sectors is highly correlated. While co-movements are less apparent in other sectors, For example, financial intermediation, other community, personal and social services and private households with employed persons sectors experience comparatively less correlated inflation rates.

Figure 4.5 plots total industry inflation of the countries under investigation. An eyeball view of Figure 4.5 shows two distinct phases of national inflation since 1970s onwards; first a period of high and volatile inflation since the early 1970s to mid 1980s when it starts slowing down and since the mid 1990s it is low and fairly stable. It is interesting to note that this pattern is followed by almost all the countries in the sample. A simple analysis of these plots indicates that a common component is present in aggregate inflation and to a greater extent in some sectoral inflation rates. Therefore, an examination of disaggregated inflation data may help suggest some nuances that are not unmasked by analysing aggregate data.

We present summary statistics in Table 4.1 which is produced by summarizing the Table B.1 presented in appendix B.[9] First and second columns of the Table 4.1 present mean and standard deviation of disaggregated and total industry inflation (in last row of Table). In the third column, average correlation within the inflation rates of each sector across countries is reported. Table 4.1 shows that sectoral inflation is more volatile than aggregate inflation.[10] The average standard deviation of sectoral inflation

[9]It is summarized by taking average of mean of each sector in every country to produce a mean value for each sector across all countries.

[10]It is also shown in Clark (2003), Bilke (2005) and Altissimo et al. (2007) and Monacelli and Sala (2009).

is 6.5, i.e. nearly three times as large as the standard deviation of aggregate inflation (i.e. 2.62).

The average inflation of tradable sectors[11] (4.67) is lower than the average inflation of non-tradable sector (6.69). The phenomenon of higher inflation rates in non-tradable sectors than tradable sectors is explained by the Balassa-Samuelson effect. The Balassa-Samuelson effect explains the inflation differentials in high and low income countries. Low income countries adopt new technologies in the sectors that are open to international trade. Consequently the tradable sectors experience higher productivity growth than non tradable sectors but the wages are expected to be approximately the same across sectors. Faster productivity growth in tradable sectors pushes up wages in all sectors, leading to an increase in wages in non tradable sectors and therefore higher relative prices (See Balassa (1964) and Samuelson (1964)). Whereas the mean standard deviation of tradable sectors is higher than the mean standard deviation of non-tradable sectors as the tradable sectors are more exposed to global shocks.

Cross-country correlation for aggregate inflation is 67 percent and for sectoral inflation, the average cross country correlation in tradable sectors across countries is higher than non-tradable sectors. The highest average cross country correlation is reported for total manufacturing sector (i.e. 55 percent) followed by transport, storage and communication sector (i.e. 54 percent) while lowest is for financial intermediation (i.e. 20 percent). Average cross country correlation in total industry (aggregate inflation) is 67 percent which is higher than the average sectoral cross country inflation (i.e. 41 percent).

To have an insight on the time series properties of aggregate and disaggregate inflation rates we apply the DF-GLS unit root test statistics proposed by Elliott et al. (1996). DF-GLS test statistics (reported in Table B.1 in Appendix B) indicate that

[11] We follow the standard classification of sectors into tradables and non-tradables as suggested in literature. agriculture, hunting, forestry and fishing, mining and quarrying and manufacturing are classified as tradable sectors and the rest as non-tradable by Goldstein and Officer (1979), and Knight and Johnson (1997). However, Gregorio et al. (1994) add Transport sector in the group of tradable sectors. We follow the classification identified by Gregorio et al. (1994) because their classification is based on sectoral inflation data of 14 OECD countries. However, the overall results in our analysis do not change even if we include transport, storage and communication in non-tradable sectors group. In view of a globalized world the distinction between tradables and non-tradables has become difficult as improvements in information technology has made many non-tradable goods as tradables. Thus for analysis purpose, we will take this into account.

for disaggregated data, the null hypothesis of a unit root is rejected almost in all cases. Therefore, we model the disaggregate inflation as a stationary process.[12]

4.3.1 Rolling Standard Deviations and Correlations in Sectoral Inflation Rates across Countries

The plot of sectoral inflation rates for 15 sectors across 15 OECD countries shows remarkable correlation in sectoral inflation rates across countries. A visual inspection of Figure 4.1 and Figure 4.2 shows that volatility of sectoral inflation has decreased over time. Table 4.1 shows that on average the highest cross country correlation in sectoral inflation is observed for total manufacturing sector and for transport, storage and communication sector and lowest cross country correlation is shared by financial intermediation sector. This is also verified in Figure 4.1 and Figure 4.2. However, it can be observed that cross country correlation and volatility does not remain constant over the sample period. Time varying measures of standard deviation and correlation can help understand how the dynamics of sectoral inflation rates has evolved over time.

To estimate the time varying volatility, we compute rolling standard deviations of sectoral inflation rates for each sector of 15 OECD countries using a centred 7-annual window. They are plotted in Figure 4.3 . Solid lines are the median, 25 percent and 75 percent percentiles. The median standard deviation clearly depicts a decline in inflation volatility for all sectors since late 1980s, reflecting “the great moderation”. However, some sectors such as agriculture, hunting, forestry and fishing, mining and quarrying and construction show a slight increase in volatility since early 2000s. Inflation is more volatile in the sectors that are classified as trdeable sectors while the sectors that are less exposed to international shocks such as public administration and defence sector, and health and social sector observe low volatile inflation. This was also observed in Table 4.1.

The spatial correlation in sectoral inflation across 15 countries is estimated over a

[12]The evidence for less persistence disaggregated inflation is provided in literature by Altissimo et al. (2007), Monacelli and Sala (2009) and Byrne et al. (2010) for UK among others.

rolling window to allow for time variation (see Stock and Watson (2010)). We use a measure based on Moran's I statistics (Moran (1950)), applied to a centred 7-annual rolling window to summarize the co-movements.

Let $X_i, (i = 1, ..., N)$, is a variable of interest then Moran's I is:

$$I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(X_i - X)(X_j - X)}{\sum_{i=1}^{N}(X_i - \bar{X})^2} \cdot \frac{N}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}} \tag{4.1}$$

where w_{ij} is a matrix of spatial weights. Here, we are interested in the co-movement of sectoral inflation over time across all countries (so $w_{ij} = 1$ for $i \neq j$) as measured by the rolling cross-correlation in sectoral inflation rates. Accordingly, Moran's I, modified in our application is:

$$\tilde{I}_t = \frac{\sum_{i=1}^{N}\sum_{j=1}^{i-1} cov(\Delta\pi_{it}, \Delta\pi_{jt})}{\sum_{i=1}^{N} var(\Delta\pi_{it})} \cdot \frac{N}{N(N-1)/2} \tag{4.2}$$

where, $cov(\Delta\pi_{it}, \Delta\pi_{jt}) = \frac{1}{7}\sum_{s=t-3}^{t+3}(\Delta\pi_{is} - \Delta\bar{\pi}_{it})(\Delta\pi_{js} - \Delta\bar{\pi}_{jt})$,
$var(\Delta\pi_{it}) = \frac{1}{7}\sum_{s=t-3}^{t+3}(\Delta\pi_{is} - \Delta\bar{\pi}_{it})^2$, $\Delta\bar{\pi}_{it} = \frac{1}{7}\sum_{s=t-3}^{t+3}\Delta\pi_{is}$ and $N = 15$

The time series $\tilde{I}_t$ for each sector is plotted in Figure 4.4. Despite considerable heterogeneity in rolling spatial correlation among countries across sectors, two peaks coinciding the first half of 1980s and 1990s are observable in all sectors. In some sectors the peak in early 1980s is higher than the peak in early 1990s while for some sectors it is vice versa. Over these time periods, ample evidence of breaks in the mean of inflation are reported in the literature (Altissimo et al. (2007), Courvoisier and Mojon (2005)). The high correlation in first half of 1980s may be a reflection of formation of the European Monetary System (EMS) in 1979 when the Benelux monetary union, France, Italy, and the Netherlands began to peg their currency to the Deutsche Mark. This was aimed to enhance the economic integration among these countries and to serve as a disciplining device to deliver levels of inflation similar to those observed in Germany (Altissimo et al. (2007)). Moreover, disinflationary monetary policy in the

United Kingdom and the United States may also be attributed for the high degree of co-movements over this time period. The second peak for high correlation in sectoral inflation rates across countries is observed in the early 1990s which may reflect the implementation of the Treaty of Maastricht in 1992, which required convergence of inflation rate in the European Union (Altissimo et al. (2007)).

In terms of magnitude of average spatial correlation among countries, the sectors which are more integrated through trade, observe high degree of co-movements than those that are less traded. For instance, correlation in agriculture, forestry, fishing and hunting sector has remained high with small variation since 1990s. The minimum correlation is observed in the financial intermediation sector. This verifies our observation in Figure 4.1 and Figure 4.2 and the average cross country correlation reported in Table 4.1. Inflation rates in the sectors that are classified as non-tradable sectors (Gregorio et al. (1994)), are also observed to be highly correlated (i.e. correlation magnitude almost approaching to what is observed by tradable sectors) during the early 1980s and 1990s. This may be due to the fact that improvements in information technology and communication has weakened the barriers between those goods and services that were thought to be tradable and those that were not (Fisher (2008)).

4.4 Econometric Methodology

In this section we present the Dynamic Factor Model of Stock and Watson (2010). The aim of our use of this model is to capture a global component, a sector specific component, and an idiosyncratic component from the inflation rate series of 15 sectors of 15 OECD countries. The global component captures the common component in all sectors across all countries and the sector specific components capture the common component in a particular sector across all countries while idiosyncratic component is unique for each sectoral inflation series. Specifically inflation is modelled as the following dynamic factor model.

$$\pi_{ijt} = \lambda_{ij} F_t + \sum_{j=1}^{N_S} \gamma_j S_{jt} + e_{ijt} \tag{4.3}$$

Where demeaned disaggregate inflation of country i in sector j at time t, π_{ijt} is function of a global factor (F_t), sector specific factors (S_{jt}) and idiosyncratic disturbance (e_{ijt}) which follows AR(1) process and λ_{ij} and γ_j are the loadings on global and sector specific factors respectively:

$$F_t = \alpha F_{t-1} + \eta_t \tag{4.4}$$

$$S_{jt} = \beta_j S_{jt-1} + \upsilon_{jt} \tag{4.5}$$

$$e_{ijt} = \rho_{ij} e_{ijt-1} + \varepsilon_{ijt} \tag{4.6}$$

The disturbances η_t, υ_{jt} and ε_{ijt} are independently distributed, where ε_{ijt} is $i.i.d$, $N(0, \sigma_\varepsilon^2)$. The factors are identified by restrictions on the factor loadings. The global factor enters all equations so λ_{ij} is unrestricted. The sector specific factors are restricted to load onto only those variables in a specific sector, so γ_j is non-zero if an inflation series i of a country is in sector j and is zero otherwise. The scale of the factors is normalized setting $\lambda'_{ij}\lambda_{ij}/N = 1$ and $\gamma'_j\gamma_j/N_{S,j} = 1$ where $\lambda_{ij} = (\lambda_{1j}, ..., \lambda_{Nij})'$, $\gamma_j = (\gamma_{1j}, ..., \gamma_{Nj})$, and N_S is number of sectors in a country. The parameters $(\lambda_{ij}, \gamma_j, \rho_{ij})$ are estimated by Gaussian Maximum Likelihood. The likelihood is maximized using the Expectation-Maximization (EM) algorithm (see Dempster et al. (1977)).

Furthermore, to make our study comparable with existing literature and as a robustness check, we estimate a single factor model using disaggregate data. This model is estimated for all sectors across all countries and then individually for each sector across all countries.

$$\pi_{it} = \lambda_i F_t + u_{it} \tag{4.7}$$

$$F_t = \alpha_i F_{t-1} + \eta_t \tag{4.8}$$

$$u_{it} = \rho_i u_{it-1} + \varepsilon_{it} \tag{4.9}$$

Where (η_t and ε_{it}) are independently distributed normal variables with zero mean and constant variances. For disaggregate data we estimate this model for all sectors across all countries ($i = 1, .., 225$) and for each sector across all countries separately (15 separate estimations each with $i = 1, .., 15$ countries). The model (equation 4.5 - equation 4.7) is estimated by maximum likelihood, using as starting values least square estimates of the coefficients using the first principal component as an estimator of F_t (see Stock and Watson 2007).

To account for national heterogeneity, we take average of the individual time-series coefficients estimates to obtain the MG (Mean Group) panel estimator,[13] $\hat{\Psi_{MG}}$:

$$\hat{\Psi}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\hat{\Psi}_i \tag{4.10}$$

Where, $\hat{\Psi}_i$ denotes the individual maximum likelihood estimates of the dynamic factor model. The standard error of the MG estimator is computed as:

$$Se(\hat{\Psi}_{MG}) = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}(\hat{\Psi}_i - \hat{\Psi}_{MG})^2} \tag{4.11}$$

MG estimates are computed for sectors across countries. Hence we take the average of estimates for a sector in each country, e.g. Austrian construction, Belgium construction, Finland construction ..........U.S. construction.

4.5 Empirical Results

This section aims to present and discuss the results of our empirical analysis. First, we present the results obtained by estimation of the Dynamic Factor Model (equation 4.3 - equation 4.6) and the variance decomposition of disaggregated inflation into a global, sector specific and idiosyncratic component. Secondly, the estimates from a single dynamic factor model (equation 4.7 equation 4.9) and the variance decomposition of

[13]See Pesaran and Smith (1995).

disaggregated inflation into a global and idiosyncratic component based on these estimates are presented. Then we report the variance decomposition of sectoral inflation into a common factor and idiosyncratic component, obtained by estimating the model (equation 4.7 equation 4.9) separately for each sector.

4.5.1 Disaggregated Inflation

The Mean Group Maximum Likelihood estimates of the model (equation 4.3 - equation 4.6) for disaggregate data are presented in Table 4.2.[14] The first and second column show the mean group factor loadings (λ and γ) on global and sector specific factors and the last two columns present average autoregressive coefficient and idiosyncratic standard deviation respectively. The factor loadings are normalized so that $\lambda'_{ij}\lambda_{ij}/N = 1$ and $\gamma'_j\gamma_j/N_{S,j} = 1$. The loadings on the global and sector specific factors show the correlation of inflation process to the global and sector specific factors.

The econometric analysis confirms our preliminary findings. A number of points in Table 4.2 are noteworthy. First, the loadings on the global factor (λ) are all positive and significant ranging from 0.67 for real estate renting and business activities sector to 1.29 for mining and quarrying. This implies that inflation process in all sectors is positively correlated with the global factor. Second, average factor loadings on global factor for tradable sector is higher (i.e. 0.96) than it is for non-tradable sectors (i.e. 0.85). However, some sectors which are classified as non-tradable sectors such as electricity, gas and water supply and the whole sale and retail sector have a high factor loading on global factor. This may reflect that the goods or services that were considered as non-tradable has become increasingly tradable due to increased globalization and technology revolution. Third, the sector specific factor loadings (γ) are also positive for all sectors except for the construction indicating that inflation process in all sectors (except Construction) have a positive correlation with sector specific factors. Fourth, the sector specific factor loadings for tradable sectors are significant and substantially higher than the sectors that are non-tradable (i.e the average loading on sector specific factor for tradable sector is 2.73 and for non-tradable sectors it is 0.86). The loadings

[14] Full results are given in Appendix B, table B.2.

are almost always insignificant for the non-tradable sectors. This is consistent with our argument that the estimation of a single common factor from disaggregated data captures the effect of a shock that is common to all sectors across all countries. However, it may not necessarily capture the effects of the international shocks that are sector specific. Hence, the loadings on global factor for tradable and non-tradable sectors are not significantly different because they capture the pattern that is common across all sectors across all countries. The higher loadings on sector specific factors for tradable sectors clearly indicate that prices of goods that are actively traded across countries observe higher co-movements than those that are less traded. This implies that highly synchronized inflation rates across sectors may be attributed to trade integration. The low persistence of idiosyncratic disturbance is shown by the autoregressive coefficient (ρ) in third column. The fourth column reports the standard deviations which indicate that average volatility of inflation in tradable sectors is higher than the average of non-tradable sectors as they are more exposed to international shocks than the non-tradable sectors.

The average proportion of variance of sectoral inflation that is explained by a global factor, sector specific factor and the idiosyncratic term based on the estimates presented in Table 4.2 is reported in Table 4.3. We find that on average 9 percent of variance in disaggregated inflation is explained by the global factor and 15 percent of it is attributed to the sector specific factors. Table 4.3 reconfirms our earlier results and it is found that the variance of disaggregated inflation that is explained by the sector specific factors is higher for tradable sectors than the non-tradable sectors. For instance, for tradable sectors, on average 24 percent of the variance of inflation is attributed to sector specific factors while for non-tradable sectors it is 11 percent. Similarly, the average variance of inflation attributed to idiosyncratic component for tradable sectors is lower (69 percent) than non-tradable sectors (76 percent). Thus it provides the evidence that inflation in the sectors that are more integrated globally observe higher co-movements across countries.

The Mean Group estimates from single factor model and the variance decomposition of disaggregated inflation into a global and idiosyncratic component is presented in

Table 4.4 and4.5 respectively. The factor loadings on the global factor (λ) reported in first numeric column of table 4.4 show a positive but small correlation of inflation process to global factor. The average of the loadings on the global factor for tradable and non-tradable sectors is almost same (i.e. 0.06 for tradable sectors and 0.05 for non-tradable sectors) which is consistent with the results produced in Table 4.2. The highest global factor loading is for mining and quarrying sector. The autoregressive coefficient (ρ) of idiosyncratic disturbance reported in second column verifies low persistence of sectoral inflation. The average share of the global sector in explaining the variance of inflation for tradable sectors is higher than it is for non-tradable sectors (i.e. 0.46 for tradable sectors and 0.42 for non-tradable sectors, reported in Table 4.5) though the difference is not significant. This is consistent with our argument that a single common factor in disaggregated inflation captures only the co movements in inflation rates that are common in all sectors across all countries (an approach used by Monacelli and Sala (2009)). Thus, the effects of international shocks that are specific to a particular sector across countries are captured by sector specific factors and not by a common factor. Hence, our results justify the approach of estimating the Dynamic Factor Model with a global factor and sector specific factors.

Table 4.5 shows that on average 43 percent of the variation in disaggregated inflation can be attributed to a single common factor. Considering the level of disaggregation used by Monacelli and Sala (2009), our results appear largely consistent with them who show that 30 percent of the variation in highly disaggregated inflation (948 product category) is attributed to a common factor. Our data set is less disaggregated than the data set employed by Monacelli and Sala (2009). They point out that generally aggregation matters while the contribution of common factor to the total variance of panel is estimated.

The estimation of the Dynamic Factor Model (equation (4.3) - equation (4.6)) provides evidence that the international components of inflation i.e. global as well as sector specific factors are important. We estimate a single factor model (equation (4.7) - equation (4.9)) for each sector across countries separately to measure the co movements of sectoral inflation in a sector across countries. The variance decomposition of sectoral inflation rates into a global factor and an idiosyncratic component based on these estimates is presented in Table 4.6. It is exhibited in Table 4.6 that a significant amount of variance of sectoral inflation is explained by a common factor for most of the sectors. It is interesting to note that the sectors which are intensively involved in international trade have significantly high global R^2 (the average global R^2 for tradable sectors is 74 percent whereas for non-tradable sectors it is 44 percent). The 89 percent of the variance of inflation of agriculture, hunting, forestry and fishing sector is explained by a global factor. The mining and quarrying sector has a comparable proportion explained by the global factor. Some of the non-tradable sectors also experience a very high inflation variance explained by a global factor i.e. 84 percent for electricity, gas and water supply and 55 percent for whole sale retail sector. Overall these results show that inflation is a global phenomenon at disaggregate level and provide support to the argument that increased trade integration and globalisation has contributed to higher co-movements of sectoral inflation across countries. However, empirical examination of the relationship between the high co-movements of sectoral inflation and trade openness is performed in the next section.

4.6 Relationship between Inflation Co-movements and Trade Openness

We find evidence that the co-movements of disaggregated inflation are higher in the tradable sectors than the non tradable sectors. This implies that the high synchronization of sectoral inflation may be attributed to openness to trade. The literature on globalization-inflation nexus emphasize increases trade integration put downward pressure on prices and a smaller increase is observed in the prices of the sectors which are more open to trade than in the sectors that are less exposed to foreign trade (see Chen et al. (2004), Gamber and Hung (2001), IMF (2006) and Binici et al. (2012) for empirical evidence). Openness to trade can affect inflation through import prices and competitive effect. In Chapter 3, we showed that high co-movements are positively and significantly related to economic globalization. For sectoral inflation, it would be interesting to investigate how common factor in sectoral inflation across countries are correlated to sectoral trade openness. We use import penetration as a measure of sectoral trade openness and obtain data on annual import penetration for five sectors from the OECD STAN indicators Database.[15]

To examine whether the co-movements of sectoral inflation rates across countries can be attributed to greater integration of factor markets, a scattered plot of global factor (reported in Table B.5 based on the estimates of single factor model (equation (4.7) - equation (4.9))) and average import penetration of each sector is presented in Figure 4.6. A scattered plot of sector specific factors (reported in Table B.3 based on the estimates by the Dynamic Factor model (equation (4.3) - equation (4.6))) and average import penetration of each sector is presented in Figure 4.7. Figure 4.8 shows the scatter plot of a common factor in each sector's inflation rate ($R^2 - F$ reported in Table 4.6, estimates based on single factor model (equation (4.7) - equation (4.9))) and average import penetration of each sector. Figure 4.6 shows a positive relationship between global factor and import penetration. The relationship between sector specific factors (and the common factor in each sector) and import penetration is also positive though it is not strong. We also used an other measure of trade openness i.e. exports and imports ratio to GDP and find the similar relationship.

4.7 Conclusion

In this chapter, we estimated the contribution of the international factors that drive the co-movements in sectoral inflation rates across 15 OECD countries. To investigate the globalization of inflation from sectoral perspective is important as it can deepen our understanding of highly synchronized inflation rates across countries. At aggregate inflation level, global factors are found to be playing important role in driving the co-movements in national inflation rates. Does this matter for sector level inflation as extent of globalization differs across sectors. We take into account the fact that international factors do not affect all the sectors with similar intensity. Hence, if

[15]The data was only available for five sectors i.e. for agriculture, hunting, forestry and fishing, mining and quarrying, total manufacturing, electricity, gas and water supply and other community, personal and social services.

globalization is responsible for the co-movements of inflation rates across countries then the sectors that are more open to trade must observe higher co-movements than the ones that are less exposed to foreign trade. We use Dynamic Factor Model to decompose the disaggregated inflation rates into a common global factor, sector specific factors and the idiosyncratic disturbances to investigate this. Once we find that the sector specific factors are important, we estimate a single dynamic factor model for each sector separately and decompose the sectoral inflation into a global and idiosyncratic component. To compare our results with Monacelli and Sala (2009), we estimate a single factor model to decompose disaggregated inflation into a global and idiosyncratic component. Our results generally agree with Monacelli and Sala (2009), once the difference in level of disaggregation is taken into account. Moreover, we investigate the relationship between the common factors in sectoral inflation and trade openness measured as import penetration.

The main contribution of the Chapter is that we examined the disaggregated sectoral inflation data and document the importance of sector specific factors in explaining the volatility of disaggregate inflation. We provide empirical evidence which supports the argument that international shocks affect prices in different sectors with different intensity. Therefore, a global factor estimation from disaggregate sectoral inflation captures the common patterns across all sectors but not the ones that are specific to particular sectors. The sectors where products are actively traded should display higher co-movements. We show that on average the loadings on the global factor and variance of disaggregate inflation explained by the global factor is not significantly different for tradable and non tradable sectors. However, the importance of sector specific factors in explaining the volatility of disaggregate inflation is substantially greater for tradable sectors than non tradable sectors. This implies that strikingly high co-movements of sectoral inflation rates are function of globalisation and increased integration of world factor and product markets. Finally, we find positive relationship between the sector specific factors and trade openness measured as import penetration.

Inflation is the key macroeconomic variable from monetary policy perspective. Given that global forces play important role in synchronization of national and sectoral inflation rates across countries, it has important implications for the conduct of monetary policy. In context of globalized inflation, should monetary policy authorities consider global developments while taking decisions? In next Chapter we will consider the monetary policy implications of our results.

Table 4.1: Sectoral inflation: Summary statistics

	Sector	**Average inflation**	**St.Deviation**	**Average cross-country correlation**
Tradable Sectors	Agri, hunting, forestry and fishing	3.7	8.73	0.35
	Mining and Quarrying	5.89	13.3	0.34
	Total Manufacturing	4.6	5.04	0..55
	Transport, Storage and Communication	4.5	5.47	0.54
	Average	4.67	8.13	0.45
Non-Tradable Sectors	Construction	6.97	5.53	0.38
	Education	7.28	5.28	0.38
	Electricity, Gas and Water supply	5.11	9.12	0.36
	Financial intermediation	5.63	9.11	0.2
	Hotels and Restaurants	7.65	5.2	0.4
	Health and Social work	7.17	5.02	0.48
	Other com, Pers and S.Services	7.23	4.9	0.49
	Public Admin and Defence	7.00	5.13	0.49
	Pvt h.holds with empl persons	7.28	5.31	0.42
	Real Est, Renting and Bus Activities	6.68	4.6	0.42
	Whole Sale and Retail	5.61	5.22	0.53
	Average	6.69	5.86	0.41
Total Industry	Average	5.85	2.62	0.67

Table 4.2: Sectoral disaggregated inflation MG-Maximum Likelihood estimates of Dynamic Factor Model

	Sector	λ	γ	ρ	σ_{ε}
Tradable Sectors	Agri, hunting, forestry and fishing	0.74*	3.40*	0.01	6.23
	Mining and Quarrying	1.29*	3.13*	0.02	9.24
	Total Manufacturing	0.84*	2.58*	0.22*	2.59
	Transport, Storage and Communication	0.95*	1.84*	0.28*	2.89
	Average	0.96	2.73	0.13	5.23
Non-Tradable Sectors	Construction	0.80*	-0.98	0.25*	3.43
	Education	0.71*	0.2	0.18*	3.01
	Electricity, Gas and Water supply	1.09*	3.46*	0.01	6.93
	Financial intermediation	0.93*	0.99	0	6.54
	Hotels and Restaurants	0.80*	1.08	0.21*	3.03
	Health and Social work	0.82*	0.87	0.40*	2.78
	Other com, Personal and S. Services	0.83*	0.28	0.34*	2.56
	Public Admin and Defence	0.87*	0.44	0.19*	2.49
	Pvt households with empl persons	0.84*	1.1	0.23*	2.89
	Real Est, Renting and Bus Activities	0.67*	0.36	0.28*	2.68
	Whole Sale and Retail	0.94*	1.73	0.23*	2.65
	Average	0.85	0.86	0.21	3.54

Notes: This table shows Mean Group (MG)-Maximum Likelihood Estimates of the dynamic factor model (4.3) (4.6) using disaggregated inflation. The Mean Group is computed by taking the average of Maximum Likelihood estimates (given in Table B.2 in Appendix B) for each sector across 15 sample countries. λ,γ are factor loading on global factor and sector specific factors respectively, ρ is autoregressive coefficient of the disturbance term and σ_{ε} denotes disturbance variance. * indicates statistical significance at 5 percent level.

Table 4.3: Variance decomposition of sectoral disaggregated inflation into global, sector-specific and idiosyncratic component

	Sector	R^2-F	R^2-S	R^2-e
Tradable Sectors	Agri, Hunting, Forestry and Fishing	0.03	0.28	0.69
	Mining and Quarrying	0.02	0.23	0.75
	Total Manufacturing	0.12	0.23	0.65
	Transport, Storage and Communication	0.11	0.21	0.68
	Average	0.07	0.24	0.69
Non-Tradable Sectors	Construction	0.07	0.02	0.91
	Education	0.09	0.06	0.85
	Electricity, water supply and Gas	0.03	0.14	0.83
	Financial intermediation	0.04	0.15	0.81
	Hotels and Restaurants	0.08	0.18	0.73
	Health and social work	0.13	0.13	0.74
	Other Com Personal and S. Services	0.14	0.13	0.73
	Public Admin and Defence	0.17	0.05	0.78
	Pvt h.holds with empl persons	0.1	0.11	0.79
	Real Est Renting and bus Activities	0.12	0.1	0.77
	Whole sale and retail trade	0.13	0.17	0.7
	Average	0.1	0.11	0.78
Total Average		0.09	0.15	0.76

Notes: This table shows the average variance decomposition of sectoral disaggregated inflation rate (see Table B.3 in Appendix B for full results). First, second and third columns show the fraction of variance attributed to global factor F (R^2-F), sector specific factor S (R^2-S) and the idiosyncratic disturbance term e (R^2-e) respectively.

Table 4.4: Sectoral disaggregated inflation MG-Maximum Likelihood estimates by single factor model

	Sectors	λ	ρ	σ_{ε}
Tradable Sectors	Agri, Hunting, Forestry and Fishing	0.04*	0.16*	3.02
	Mining and Quarrying	0.10*	0.17*	6.42
	Total Manufacturing	0.05*	0.19*	4.82
	Transport Storage and Communication	0.07*	0.18*	6.06
	Average	0.06	0.17	5.08
Non-Tradable Sectors	Construction	0.05*	0.18*	4.37
	Education	0.06*	0.16*	5.19
	Electricity, Gas and Water supply	0.06*	0.24*	2.92
	Financial Intermediation	0.03*	0.26	3.29
	Hotels and Restaurants	0.07*	0.47*	4.97
	Health and Social Work	0.09*	0.04	4.38
	Other Com Personal and S. Services	0.03*	-0.01	5.04
	Public Admin and Defence	0.03*	0.49*	3.81
	Pvt h.holds with Empl Persons	0.08*	0.41*	6.06
	Real Est Renting and Bus Activities	0.08*	0.27*	3.24
	Whole sale and retail trade	0.03*	0.1	4.92
	Average	0.05	0.23	4.38

Notes: This table shows the Mean Group (MG)-Maximum Likelihood estimates of the single factor model (4.7) - (4.9). These are computed by taking the average of Maximum Likelihood time series estimation results for each sector across 15 sample countries (Table B.4 in Appendix B). λ is factor loading on global factor, ρ is autoregressive coefficient of the disturbance term and σ_{ε} denotes disturbance variance. * indicates statistical significance at 5 level level.

Table 4.5: Variance decomposition of sectoral disaggregated inflation into global and idiosyncratic component

	Sectors	$R^2 - F$	$R^2 - e$
Tradable Sectors	Agri, Hunting, Forestry and Fishing	0.23	0.77
	Mining and Quarrying	0.69	0.31
	Total Manufacturing	0.34	0.66
	Transport Storage and Communication	0.57	0.43
	Average	0.46	0.54
Non-Tradable Sectors	Construction	0.31	0.69
	Education	0.47	0.53
	Electricity, Gas and Water supply	0.49	0.51
	Financial Intermediation	0.17	0.83
	Hotels and Restaurants	0.62	0.38
	Health and Social Work	0.65	0.35
	Other Community Personal and S. Services	0.15	0.85
	Public Admin and Defence	0.24	0.76
	Pvt h.holds with empl persons	0.65	0.35
	Real Est Renting and Bus Activities	0.6	0.4
	Whole sale and retail trade	0.22	0.78
	Average	0.42	0.58
	Total Average	0.43	0.57

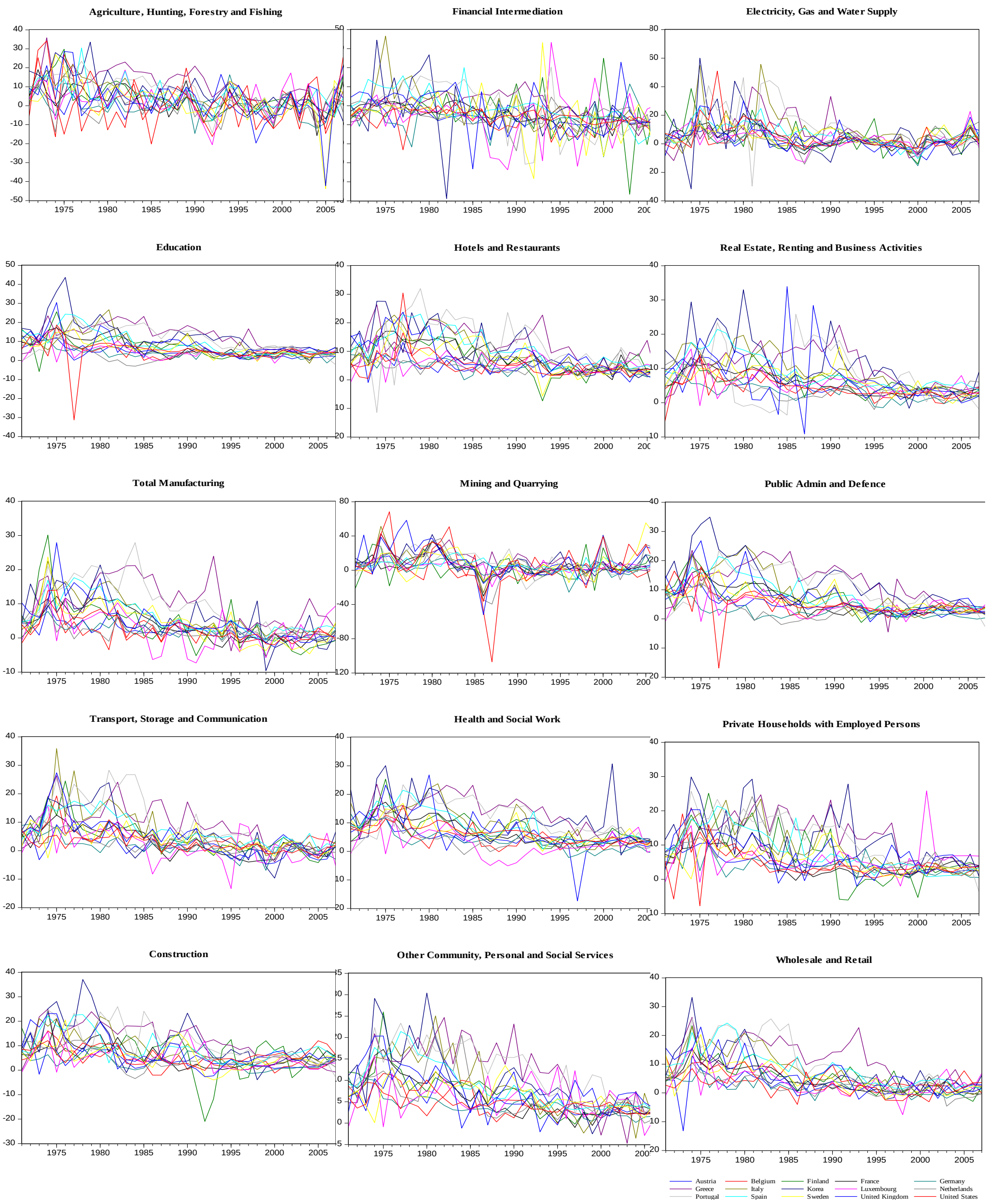
Notes: This table shows the average variance decomposition of sectoral disaggregated inflation rate (see Table B.5 in Appendix B). First and second columns show the fraction of variance of disaggregated inflation attributed to global factor F ($R^2 - F$) and the idiosyncratic disturbance term e ($R^2 - e$) respectively.

Table 4.6: Variance decomposition of disaggregated inflation estimated for each sector across countries (estimated individually) into global and idiosyncratic component

	Sectors	$R^2 - F$	$R^2 - e$
Tradable Sectors	Agri, Hunting, Forestry and Fishing	0.89	0.11
	Mining and Quarrying	0.88	0.12
	Total Manufacturing	0.63	0.37
	Transport Storage and Communication	0.58	0.42
	Average	0.74	0.26
Non-Tradable Sectors	Construction	0.4	0.6
	Education	0.42	0.58
	Electricity, Gas and Water supply	0.84	0.15
	Financial Intermediation	0.28	0.72
	Hotels and Restaurants	0.44	0.56
	Health and Social Work	0.46	0.54
	Other Community Personal and s. services	0.42	0.58
	Public Admin and Defence	0.43	0.57
	Pvt h.holds with employed persons	0.31	0.69
	Real Est Renting and Bus Activities	0.27	0.73
	Whole sale and retail trade	0.55	0.45
	Average	0.44	0.56

Notes: This table shows average variance decomposition of sectoral disaggregated inflation rate estimated for each sectors across countries separately. First and second columns show the fraction of variance attributed to global factor F ($R^2 - F$) and the idiosyncratic disturbance e ($R^2 - e$) respectively. Full results are given in Table B.6 in Appendix B.

Figure 4.1: Sectoral inflation across 15 OECD countries



Note: The figure shows the sectoral inflation rates across 15 OECD countries for each sector.

Figure 4.2: Changes in sectoral inflation rates of 15 OECD countries for 15 sectors

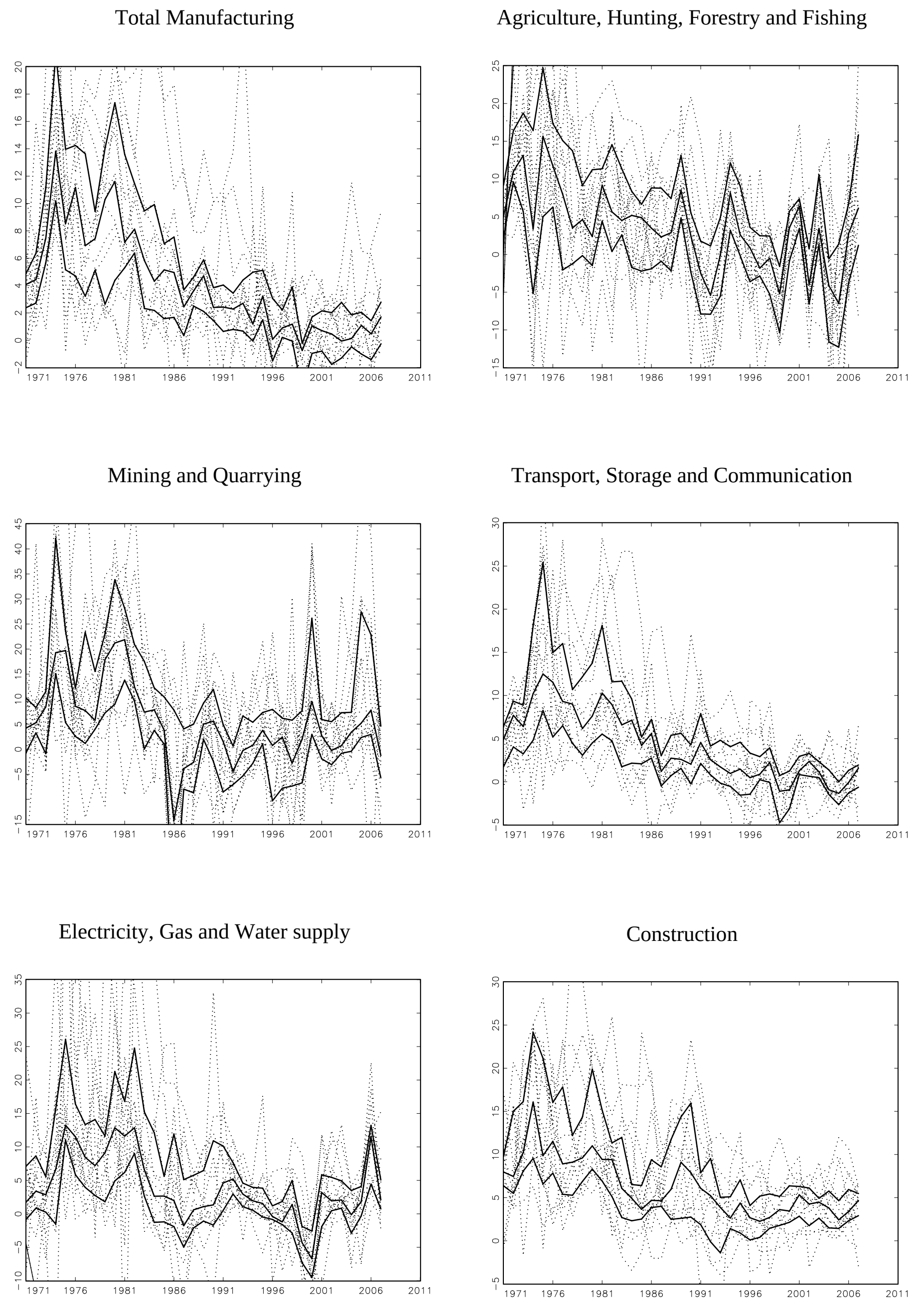


Figure 4.2: Changes in sectoral inflation rates of 15 OECD countries for 15 sectors (Continued...)

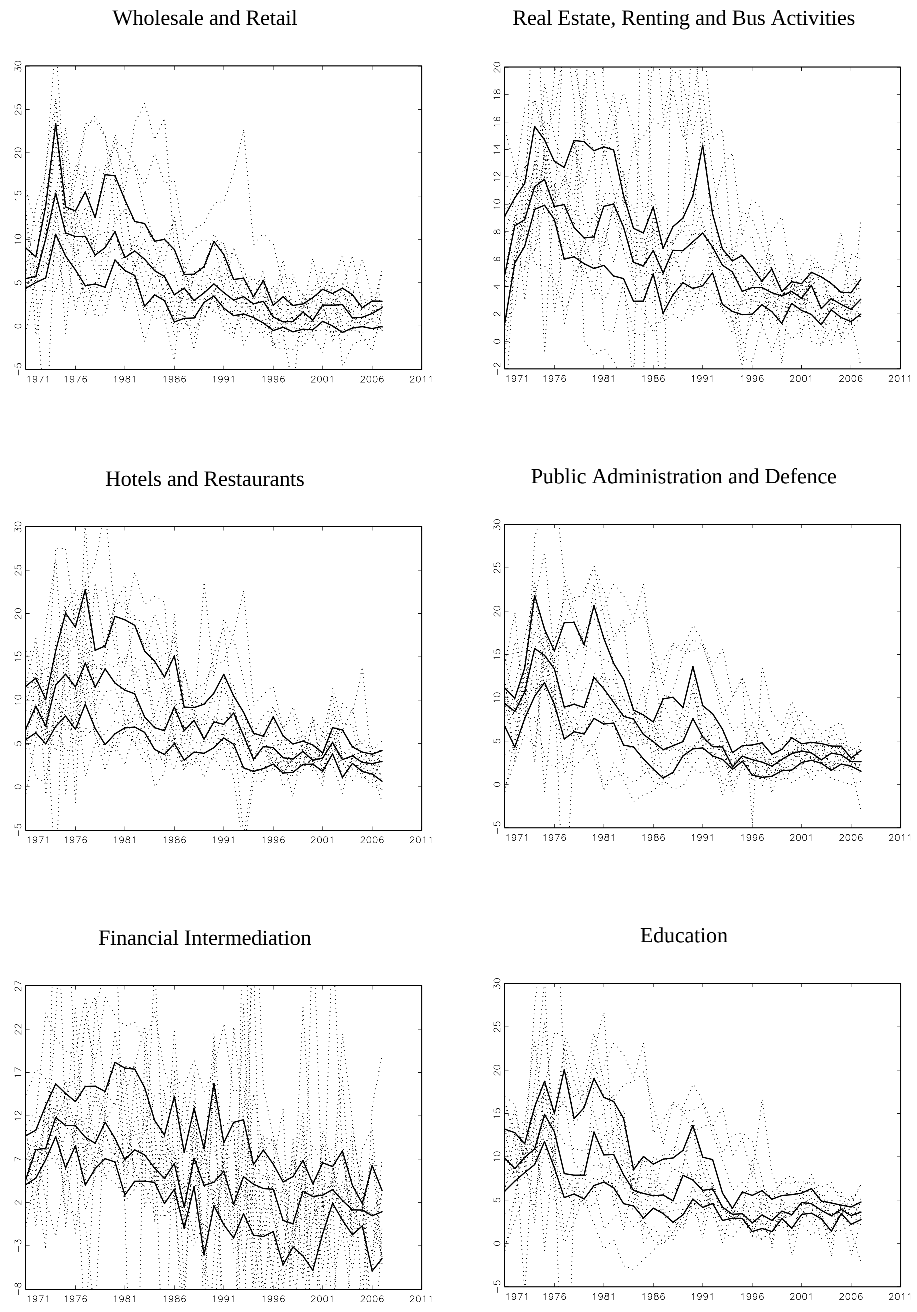
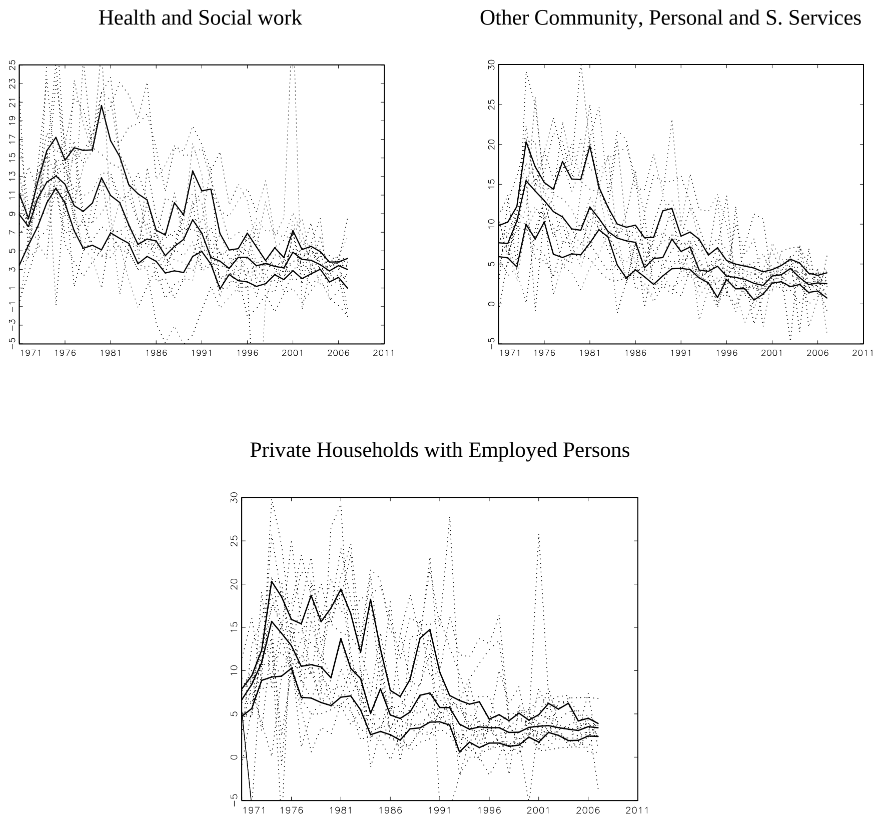


Figure 4.2: Changes in sectoral inflation rates of 15 OECD countries for 15 sectors (Continued. . .)



Note: The dotted lines are the first differenced sectoral inflation rates for 15 OECD countries across 15 sectors. The median, 25 and 75 percentiles are in solid lines.

Figure 4.3: Rolling standard deviation of sectoral inflation rates for 15 sectors across 15 OECD countries

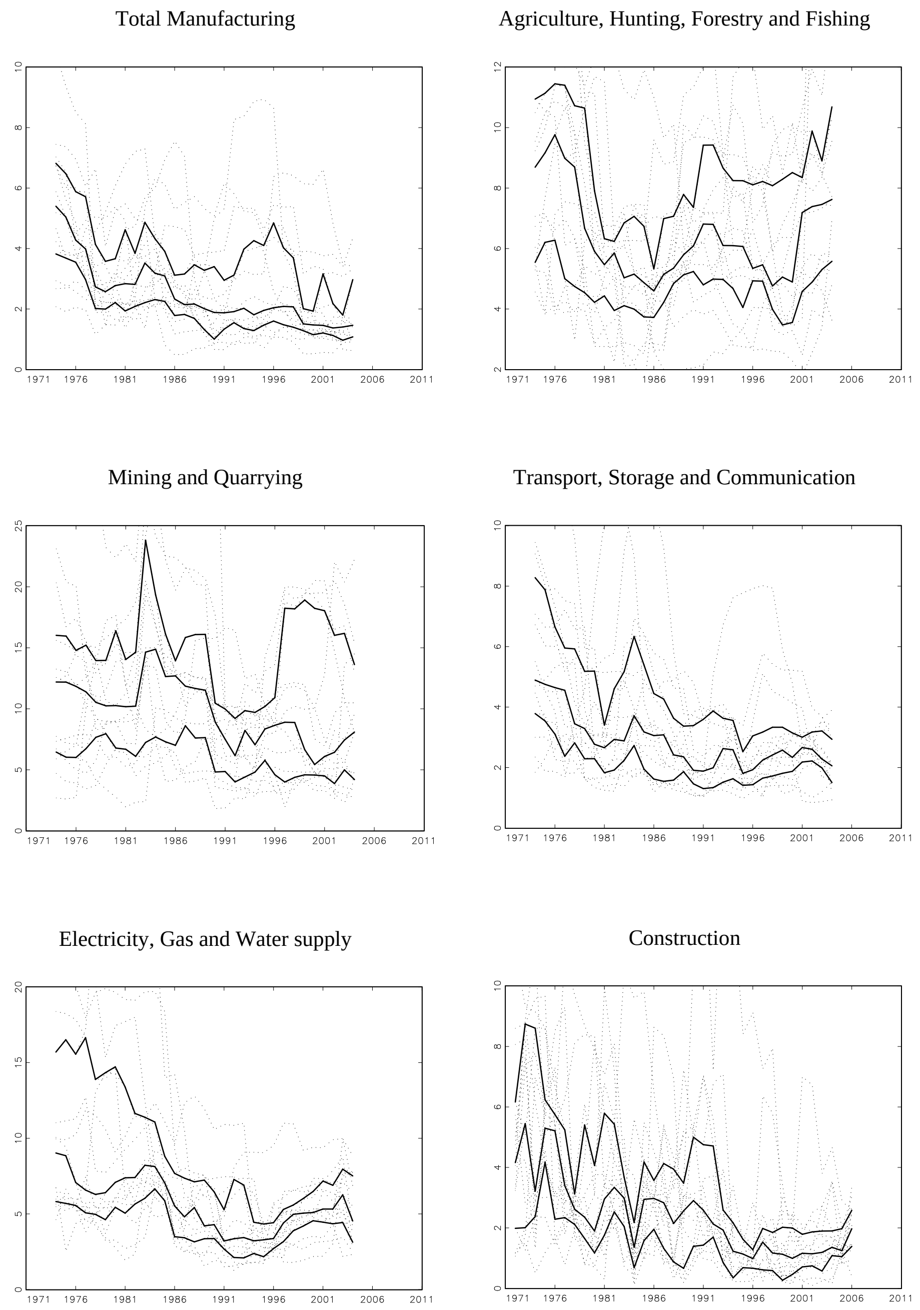


Figure 4.3: Rolling standard deviation of sectoral inflation rates for 15 sectors across 15 OECD countries (Continued. . .)

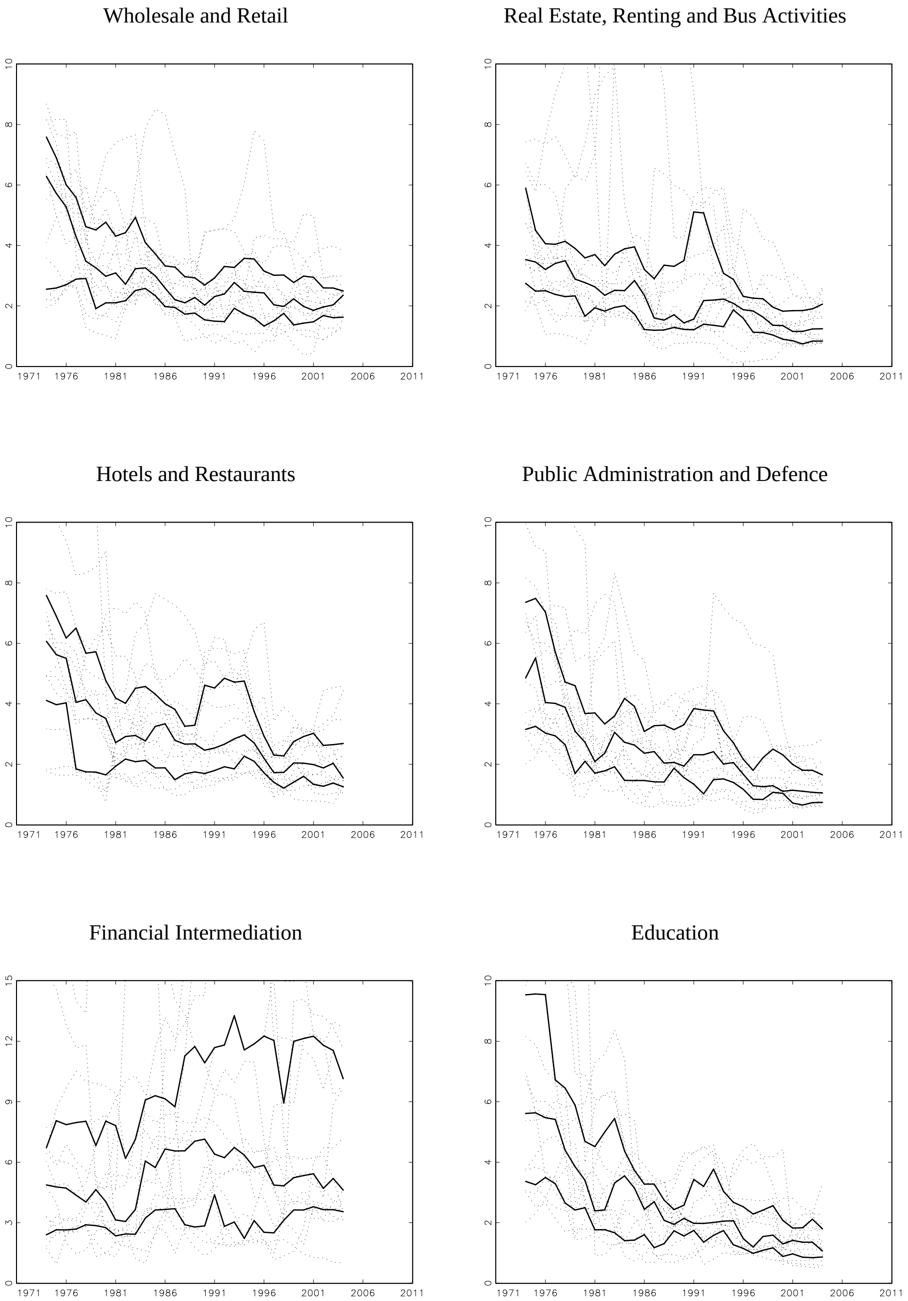
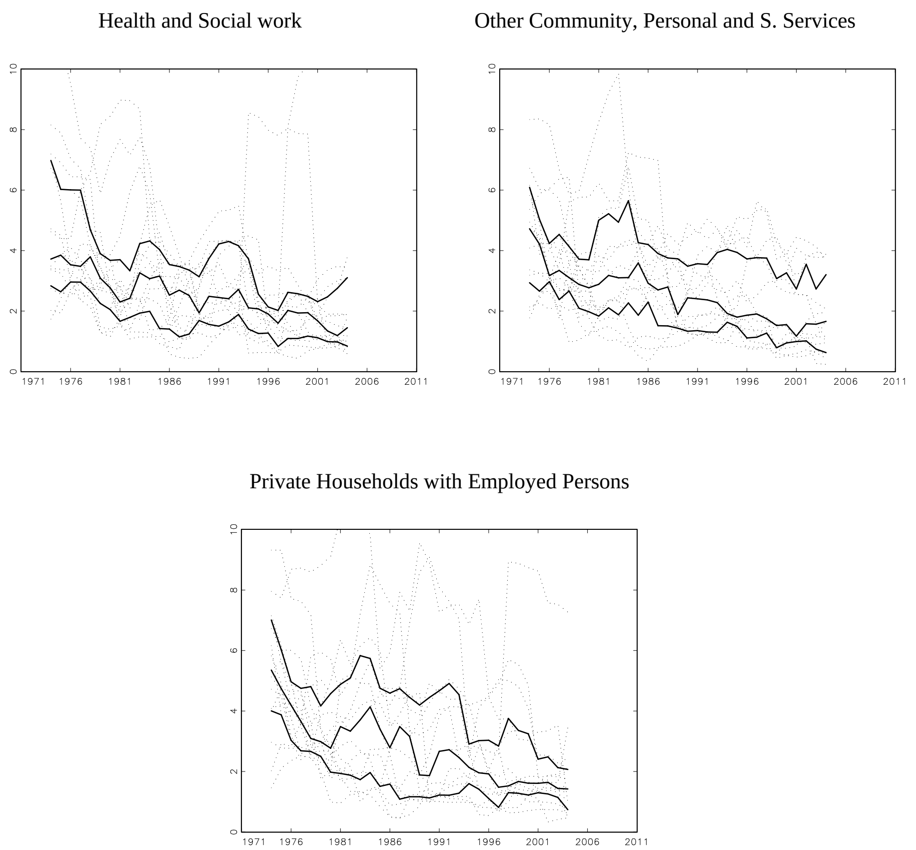


Figure 4.3: Rolling standard deviation of sectoral inflation rates for 15 sectors across 15 OECD countries (Continued...)



Note: The figure shows median, 25 percent, and 75 percent percentiles of rolling standard deviations of sectoral inflation rates across 15 OECD countries.

Figure 4.4: Rolling average spatial correlation in the sectoral inflation rates across 15 OECD countries

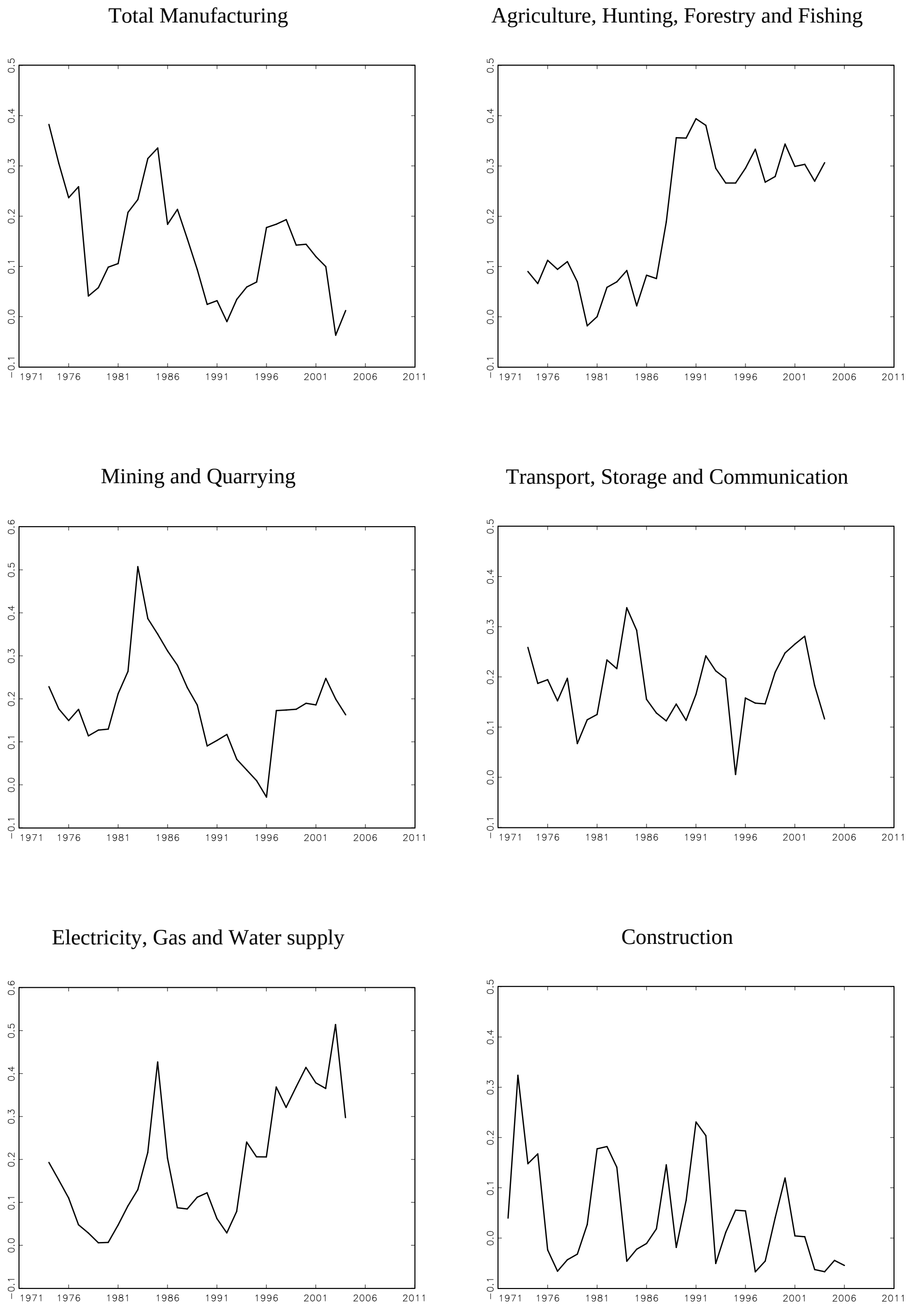


Figure 4.4: Rolling average spatial correlation in the sectoral inflation rates across 15 OECD countries (continued. . .)

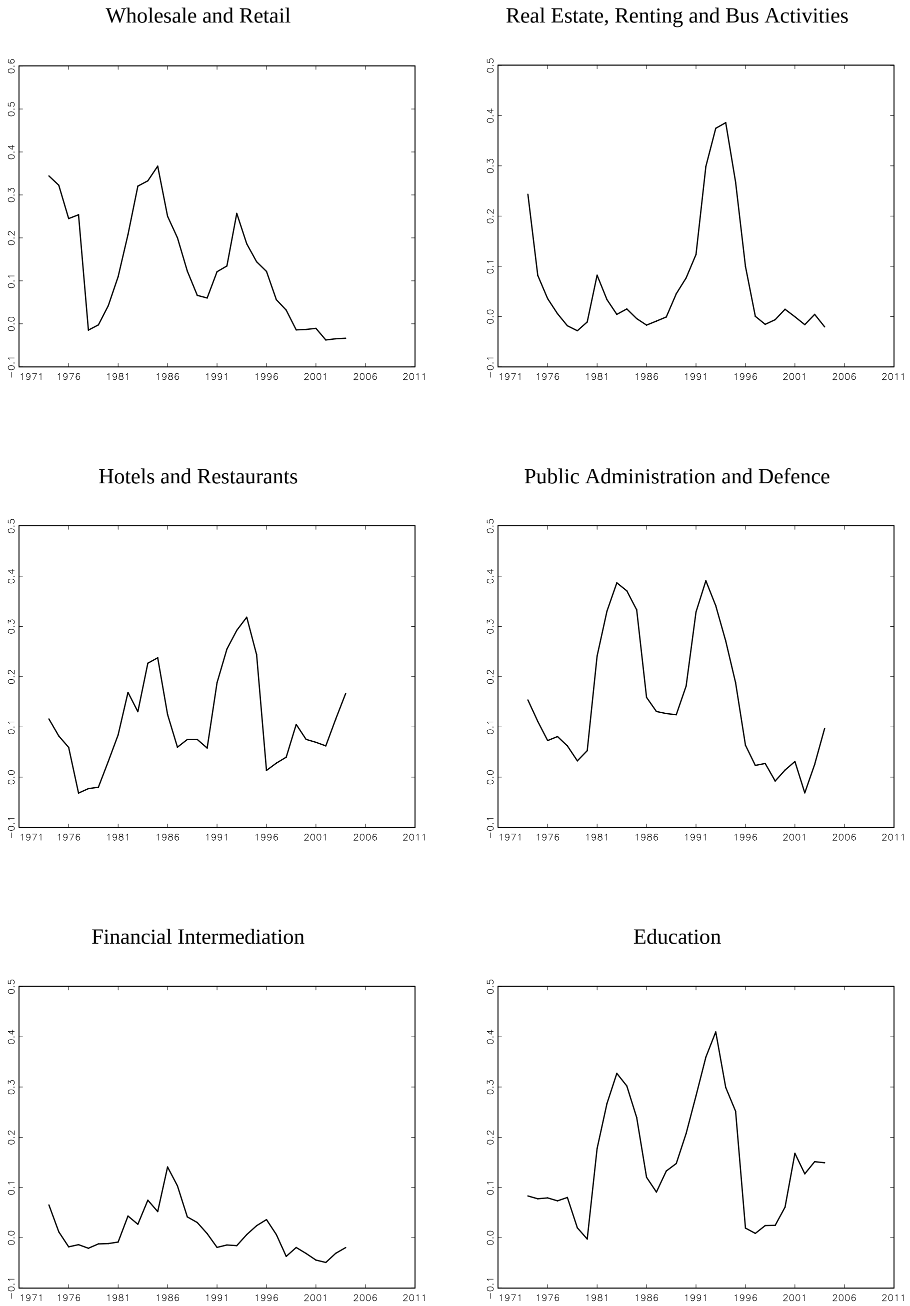
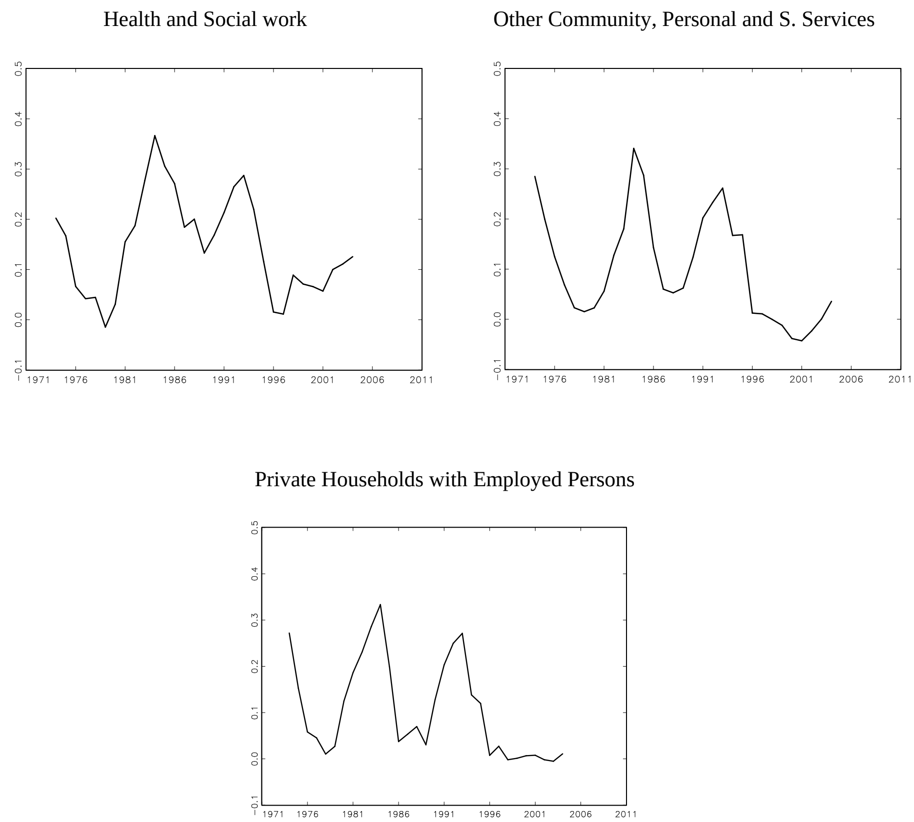
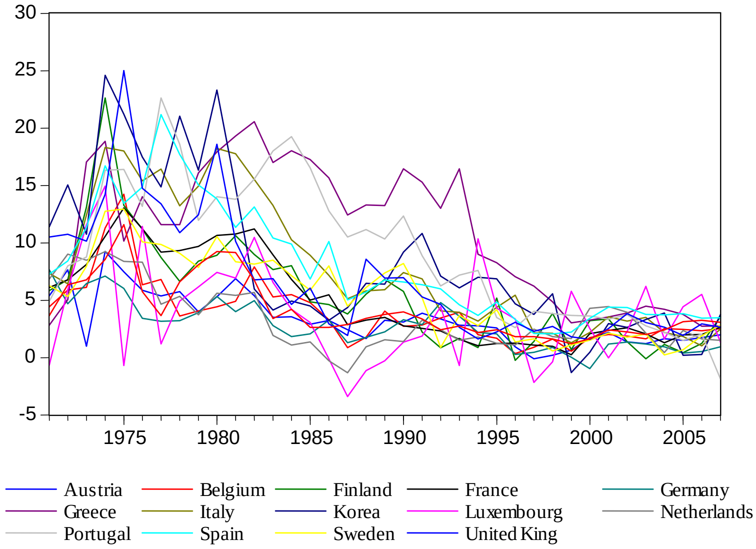


Figure 4.4: Rolling average spatial correlation in the sectoral inflation rates across 15 OECD countries (continued...)



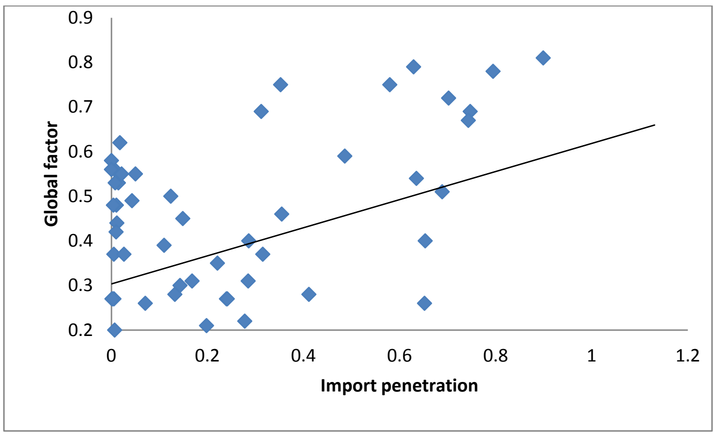
Note: Rolling average spatial correlation in sectoral inflation rates for 15 sector across 15 OECD countries as measured by the modified Moran's I statistics $\bar{I}_t$.

Figure 4.5: Aggregate inflation rates of 15 OECD countries



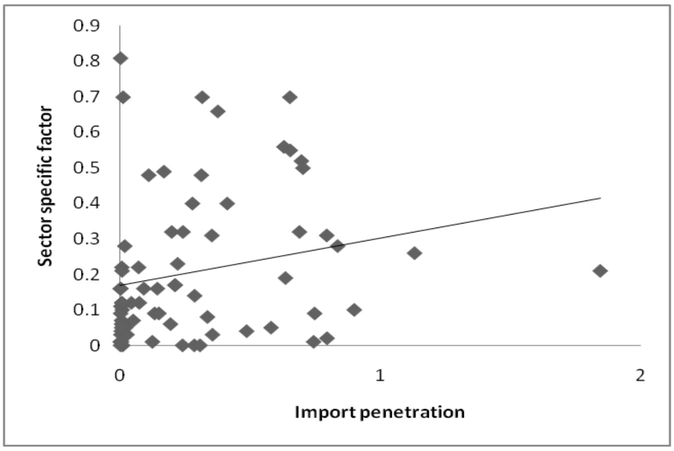
Note: The figure shows annual aggregate inflation rates of 15 OECD countries.

Figure 4.6: Relationship between global factor and import penetration



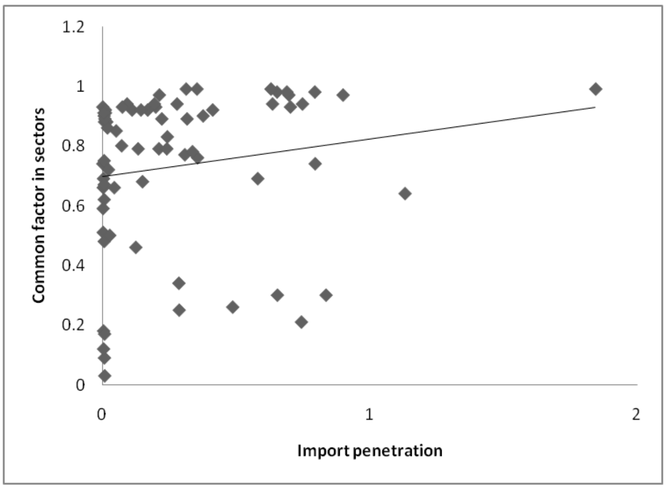
Note: The global factor estimated by model (1) to (4) and import penetration for five sectors is plotted here, as data on import penetration from OECD STAN indicators database is available only for five sectors, i.e. for Agriculture, hunting, forestry and fishing, Mining and quarrying, Total manufacturing, Electricity, Gas and water supply and Other community, personal and social services.

Figure 4.7: Relationship between sector specific factor and import penetration



Note: The sector specific factors estimated by model (1) to (4) and import penetration for five sectors is plotted here, as data on import penetration from OECD STAN indicators database is available only for five sectors, i.e. for Agriculture, hunting, forestry and fishing, Mining and quarrying, Total manufacturing, Electricity, Gas and water supply and Other community, personal and social services.

Figure 4.8: Relationship between the common factor in each sector across countries and import penetration



Note: The plot shows the relationship between common factor in each sector and import penetration for five sectors. The common factor in each sector is estimated by model (5) to (7).

Appendices

Appendix B

Appendix to Chapter 4: Does Disaggregation Matter for Inflation Globalization?

Table B.1: Inflation rates; Summary statistics

Country	Average Inflation Rate	Standard Deviation	DF-GLS Test Statistic	Average Inflation Rate	Standard Deviation	DF-GLS Test Statistic	Average Inflation Rate	Standard Deviation	DF-GLS Test Statistic	Average Inflation Rate	Standard Deviation	DF-GLS Test Statistic
	Agri, hunting, forestry and fishing			Financial intermediation			Other comm, Personal and S. Services			Total Manufacturing		
Austria	0.62	5.14	-4.44**	3.86	4.16	-3.52**	5.84	3.37	-3.14**	2.09	2.25	-3.45**
Belgium	0.6	10.58	-6.28**	2.94	5.86	-3.52**	4.77	3.28	-2.21*	2.04	3	-4.41**
Finland	4.1	7.95	-2.66**	5.76	11.65	-7.20**	7	5.05	-2.04*	3.68	7.13	-3.11**
France	2.84	7.37	-5.51**	5.08	4.88	-2.30*	5.77	4.66	-1.29	3.7	4.68	-1.26
Germany	0.5	7.28	-4.76**	2.95	8.73	-4.84**	4.08	2.55	-1.61	2.48	2.25	-3.31**
Greece	10.85	8.78	-3.54**	9.29	6.92	-1.38	11.56	7.45	-2.33*	*10.43	6.84	-2.43*
Itlay	5.21	7	-2.14*	8.3	10.49	-3.63**	8.54	6.68	-2.34*	6.65	5.65	-2.06*
Korea	7.55	9.44	-2.73**	7.27	13.47	-5.68**	9.46	7.94	-2.44*	5.49	6.59	-3.07**
Luxembourg	3.04	8.29	-5.14**	3.52	13.07	-5.28**	5.91	4.37	-5.11**	2.67	5.71	-4.11**
Netherlands	0.21	7.2	-6.22**	3.64	6.91	-3.42**	6.33	5.21	-2.05*	2.03	2.59	-4.37**
Portugal	6.76	8.37	-2.71**	7.38	13.56	-3.88**	12.06	6.49	-1.63	6.27	5.14	-1.75
Spain	5.13	7.52	-5.09**	9.05	8.67	-3.05**	8.61	5.43	-1.04	4.17	5.9	-2.65**
Sweden	2.51	11.02	-4.88**	4.03	12.84	-6.90 **	6.56	3.21	-3.10**	5.44	6.21	-2.43*
U.K	3.77	12.54	-4.91**	7.3	11.27	-4.77**	7.43	5.53	-2.76**	2.69	3.86	-2.74**
United States	1.88	12.53	-4.75**	4.06	4.26	-6.12**	4.56	2.16	-2.08*	9.26	7.87	-1.54
	Construction			Hotels and Restaurants			Public admin and defence			Transport, Storage and Communication		
Austria	4.02	3.33	-4.37**	4.86	3.6	-2.90**	4.5	3.08	-1.73	2.09	3.48	-4.11**
Belgium	3.99	4.01	-2.58*	5.23	2.83	-3.67**	4.77	3.62	-2.19*	4.24	3.45	-3.05**
Finland	6.61	8.2	-3.12**	7.12	5.5	-2.15*	7.14	5.02	-1.55	4.79	5.75	-2.55*
France	5.9	4.78	-2.39*	7.84	5.02	-1.97*	5.91	4.86	-1.12	2.77	4.7	-1.69
Germany	3.57	3.12	-2.19 *	4.56	2.8	-3.23**	2.36	2.36	-2.05*	1.38	3.49	-2.44*
Greece	11.65	7.38	-2.03*	11.93	6.34	-2.66**	12.42	6.85	-2.37*	8.67	7.13	-2.34*
Itlay	8.44	6.2	-2.34*	9.56	6.52	-1.66	9.05	7.54	-2.11*	6.7	8.29	-3.87**
Korea	10.57	9.3	-2.32*	10.34	7.76	-2.81**	12.78	8.35	-1.89	5.93	7.91	-2.14*
Luxembourg	4.8	4.57	-4.06**	5.59	3.43	-4.23**	4.51	3.65	-4.34**	1.77	6.14	-4.19**
Netherlands	4.99	4	-1.27	4.4	2.27	-3.71**	3.46	3.57	-1.29	2.34	3.7	-1.89
Portugal	11.19	7.31	-2.91**	11.86	9.3	-3.89**	10.14	6.95	-1.53	8.93	9.14	-1.88
Spain	9.29	5.97	-2.15*	10.57	5.88	-1.6	8.44	5.77	-1.34	7.01	5.34	-1.85
Sweden	5.57	4.89	-3.17**	7.36	5.56	-2.40*	6.56	4.03	-2.29*	3.7	3.89	-4.53**
U.K	7.63	6.62	-2.23*	8.32	6.36	-1.73	7.82	6.14	-2.33**	4.75	6.78	-2.07*
United States	6.3	3.35	-2.72**	5.25	5.09	-4.26**	5.27	5.26	-5.16**	2.35	2.96	-2.93**
	Education			Health and Social work			Pvt h.holds with empl persons			Whole sale and Retail trade		
Austria	4.56	3.08	-1.74	4.45	4.73	-3.43**	4.88	2.56	-1.8	2.33	3.89	-5.95**
Belgium	4.98	3.71	-2.44*	4.89	3.23	-2.54*	4.82	4.01	-2.98**	5.42	3.49	-2.17*
Finland	6.96	5.62	-2.94**	7.6	4.95	-2.51*	7.18	7.77	-2.68**	5.36	5.32	-2.73**
France	6.88	4.73	-1.86	6.81	4.4	-1.46	4.84	3.99	-1.87	4.36	4.12	-1.55
Germany	3.88	3.01	-2.01*	3.58	3.89	-1.13	3.87	2.97	-4.86**	2.36	2.78	-3.43**
Greece	12.62	6.52	-1.83	12.42	6.55	-1.7	12.5	6.52	-2.33*	10.97	7.15	-2.15*
Itlay	8.48	6.45	-2.56*	8.99	6.39	-1.41	8.93	6.52	-2.18*	7.62	6.86	-1.62
Korea	13.08	8.77	-2.11*	11.09	7.97	-3.87**	11.52	8.26	-3.93**	7.21	7.41	-2.63**
Luxembourg	4.36	3.69	-4.42**	2.88	4.86	-3.44**	6.16	4.75	-4.99**	3.57	4.46	-4.35**
Netherlands	4.27	3.82	-1.53	4.49	3.41	-1.6	7.34	5.92	-2.07*	2.72	3.32	-2.30*
Portugal	10.52	6.58	-1.49	10.61	6.54	-1.55	11.68	6.9	-1.24	10.09	8.57	-1.56
Spain	9.01	6.24	-1.29	8.68	5.59	-1.67	8.3	6.12	-1.56	8.64	6.32	-1.64
Sweden	6.56	4.1	-2.54*	6.86	3.86	-2.54*	5.65	3.56	-2.72**	4.87	5.14	-2.46*
U.K	7.91	5.85	-3.80 **	7.82	6.1	-2.84**	7.43	5.53	-2.76**	6.55	6.04	-2.18*
United States	5.13	7	-6.43**	6.34	2.95	-2.08*	4.15	4.28	-7.00**	2.16	3.46	-3.61**
	Electricity, Gas and Water Supply			Mining and quarrying			Real Est, Renting and Bus Activities			Total Industry		
Austria	2.16	6.32	-3.05**	3.94	7.7	-3.84**	5.7	3.46	-2.12*	3.33	2.09	-2.86 **
Belgium	1.62	4.67	-4.03**	1.29	27.06	-3.76**	4.48	3.09	-3.03**	3.86	2.12	-2.26 *
Finland	5.24	10.57	-3.88**	2.99	14.05	-5.00**	6.05	3.14	-2.51*	5.48	3.24	-2.10 *
France	3.39	6.61	-2.65**	3.78	11.89	-3.96**	5.54	3.17	-1.2	4.99	1.21	-0.82
Germany	2.48	5.75	-3.59**	2.44	9.04	-3.42**	3.08	2.61	-2.07*	2.73	1.26	-1.44
Greece	8.27	11.57	-3.40**	10.23	9.39	-4.08**	10.25	5.56	-1.73	10.81	3.42	-1.48
Itlay	9.1	13.33	-5.23**	7.61	12.99	-3.32**	9.17	5.19	-1.57	7.87	2.18	-0.97
Korea	5.19	16.08	-5.19**	9.44	12.27	-3.56**	11.22	7.95	-3.21**	8.32	4.3	-1.85
Luxembourg	2.96	6.8	-4.46**	3.54	6.23	-5.24**	5.3	3.32	-4.17**	3.8	5.41	-4.20 **
Netherlands	2.77	5.82	-3.68**	4.91	16.7	-3.88**	4.42	3.46	-1.52	3.39	1.49	-1.44
Portugal	10.33	16.39	-4.45**	6.94	12.23	-3.07**	7.47	7.91	-2.81**	9.18	3.05	-1.11
Spain	6.66	7.82	-2.80**	6.06	6.3	-4.90**	8.93	5.16	-1.07	7.87	2.35	-1.27
Sweden	5.7	6.02	-4.47**	7.43	15.69	-3.48**	6.76	3.69	-2.75**	5.38	1.97	-1.54
U.K	4.84	8.82	-3.98**	10.47	20.95	-3.94**	7.44	8.18	-5.52**	6.75	3.63	-1.92
United States	6.08	10.32	-3.87**	7.37	17.01	-4.01**	4.37	3.2	-2.36*	4.13	1.67	-1.95

Table B.2: Sectoral disaggregated inflation: Maximum Likelihood estimates

Country	λ	γ	ρ	σ_ϵ	λ	γ	ρ	σ_ϵ	λ	γ	ρ	σ_ϵ
	Agri, hunting, forestry and fishing				Hotels and Restaurants				Pvt h.holds with empl persons			
Austria	0.26	1.9	0	4.48	0.32	1.13	0.11	2.81	0.44	-0.45	0.54	1.35
Belgium	0.4	7.05	-0.16	6.68	0.42	2.17	0.27	1.95	0.66	-1.95	0.14	2.61
Finland	1.16	1.53	0.3	5.58	1.03	2.52	0.35	2.84	1.37	-3.26	0	4.79
France	0.61	4.83	-0.59	3.43	1.04	0.54	0.08	2.38	0.7	0.72	0.47	2.03
Germany	0.05	4.01	0.2	5.75	0.35	-0.49	0.11	2.23	0.33	1.46	-0.2	2.41
Greece	1.15	2.54	0.14	6.55	0.93	-5.73	0.44	3.49	0.99	1.57	0.43	4.26
Itlay	1.34	2.58	0.21	2.67	1.4	1.11	0.12	2.48	1.38	0.92	-0.07	2.9
Korea	1.58	-0.43	0.14	6.34	1.52	-1.77	0	4.22	1.25	13.82	0.39	0.28
Luxembourg	0.07	6.37	-0.03	4.42	0.27	-5.13	-0.1	1.71	0.1	0.69	-0.07	4.57
Netherlands	0.19	4.24	-0.07	5.35	0.2	-0.47	0.27	1.98	0.88	1.07	0.55	3.46
Portugal	1.39	2.85	0.26	4.73	0.69	10.43	0.47	6.75	1.6	1.23	0.64	2.72
Spain	0.79	2.75	-0.23	5.95	1.14	1.56	0.37	2.74	1.31	-1.85	0.26	2.18
Sweden	1.22	2.31	-0.09	9.36	0.87	2.39	0.34	3.43	0.33	0.66	0.48	2.67
U.K	0.96	4.73	-0.09	10.57	1.16	3.54	0.46	2.86	0.93	2.49	0.35	3.48
United States	-0.02	3.82	0.11	11.6	0.67	4.35	-0.11	3.68	0.4	-0.51	-0.38	3.6
	Construction				Health and Social work				Real Est, Renting and Bus Activities			
Austria	0.42	-0.28	-0.09	2.75	0.61	1.7	0.27	3.75	0.57	-1.13	0.38	2.08
Belgium	0.72	-2.6	0.3	2.41	0.41	1.56	0.38	2.27	0.55	1.23	0	1.99
Finland	0.65	-5.68	0.38	6.71	0.91	5.61	0.47	2.62	0.56	-0.01	0.19	1.89
France	0.92	-5.28	-0.07	2.23	0.96	-0.02	0.25	1.48	0.67	0.98	0.46	0.94
Germany	0.26	2.03	0.64	2.08	0.6	1.9	0.58	1.6	0.35	7.6	0.36	0.22
Greece	1.2	7.28	0.02	3.68	1.17	-2.9	0.64	3.18	0.85	-3.09	0.77	2.81
Itlay	1.31	-1.44	-0.22	2.77	1.25	-0.44	0.35	2.97	1.03	3.63	0.4	2.26
Korea	1.52	0.51	0.49	5.74	1.03	-1.98	0.05	6.44	1.44	-2.67	0.16	5.15
Luxembourg	0.48	2.54	-0.03	3.79	0.49	-8.84	0.52	3.29	0.27	6.09	-0.4	2.39
Netherlands	0.32	0.74	0.8	1.87	0.52	-0.35	0.77	1.73	0.26	1.58	0.76	1.67
Portugal	1.32	3.45	-0.16	4.14	0.94	8.19	0.8	2.62	0.59	-9.36	0.66	5.84
Spain	1.12	-3.05	0.5	3.26	1.2	-0.26	0.13	2.21	1.11	-0.92	0.58	1.38
Sweden	0.53	-1.39	0.36	3.9	0.7	2.53	0.24	2.27	0.59	-0.63	0.23	2.6
U.K	0.98	-6.58	0.51	3.88	1.03	2.81	0.18	4.09	0.74	2.3	-0.09	7.49
United States	0.32	-5.01	0.35	2.23	0.58	3.52	0.31	1.24	0.53	-0.09	-0.22	1.5
	Education				Mining and quarrying				Total Manufacturing			
Austria	0.61	1.71	0.38	1.52	0.96	2.75	-0.3	3.34	0.4	0.75	-0.25	1.3
Belgium	0.76	4.05	-0.1	1.64	2.83	6.71	0.09	20.1	0.32	3.53	-0.23	2.08
Finland	0.91	0.18	0.11	3.82	0.4	1.37	-0.21	12.8	1.18	9.85	0.07	2.57
France	1.09	2.43	0.2	1.78	1.28	2.89	-0.12	9.19	0.92	0.07	0.54	1.62
Germany	0.44	1.73	0.14	1.76	0.96	1.94	0.31	6.66	0.33	1.47	-0.06	1.47
Greece	0.88	-4.54	0.33	3.42	1.3	1.5	-0.03	7.06	0.82	1.76	0.5	4.83
Itlay	0.94	-3.7	0.16	3.91	2.32	3.22	-0.29	5.58	1.23	2.78	0.22	1.92
Korea	1.78	3.55	0.35	4.62	2.06	1.77	0.07	8.17	1.12	0.12	0.09	4.52
Luxembourg	0.5	2.5	-0.21	2.81	0.46	0.94	-0.18	5.62	0.53	5.89	0.12	4.44
Netherlands	0.26	2.68	0.8	1.76	1.08	6.8	-0.05	8.76	0.26	3.81	0.21	1.59
Portugal	0.51	-9.29	-0.45	1.79	1.51	0.88	0.29	9.58	1.42	0.42	0.53	3.69
Spain	0.1	-5.01	0.83	2.66	0.57	-0.4	-0.02	5.66	1.01	2.77	0.62	1.77
Sweden	0.75	-0.21	0.14	2.43	0.34	4.31	0.45	11.5	1.17	6.17	0.54	1.8
U.K	0.87	4.15	0.18	4.59	2.3	6.07	0.15	14.3	1.22	-2.17	0.17	3.22
United States	0.26	2.77	-0.11	6.77	1.05	6.25	0.17	10.5	0.77	1.47	0.2	2.02
	Electricity, Gas and Water Supply				Other comm, Personal and S.Services				Transport, Storage and Communication			
Austria	0.76	4.42	-0.06	4.14	0.58	1.3	0.14	2.26	0.45	3.85	0.23	2.27
Belgium	0.65	2.6	-0.14	3.33	0.38	-2.52	0.48	2.06	0.63	3.45	0.69	1.61
Finland	1.21	4.46	-0.05	8.14	0.91	-9.52	0.66	0.85	1.1	-1.8	0.25	3.2
France	1.09	3.77	0.12	3.81	1	-1.66	0.44	1.4	0.95	0.1	0.34	2.03
Germany	0.64	6.38	-0.14	1.96	0.34	1.99	0.44	1.33	0.46	1.46	0.32	2.38
Greece	1.39	3.83	0.3	9.2	1.22	2.88	0.43	4.65	1.31	2.38	0.46	4.14
Itlay	1.51	3.91	-0.12	11.22	1.38	-0.57	-0.11	3.21	1.5	10.94	-0.11	2.45
Korea	1.61	2.71	-0.09	14.39	1.62	4.04	0.15	3.92	1.51	1.75	0.43	4.06
Luxembourg	0.6	4.62	-0.1	5.35	0.23	7.69	-0.11	3.5	0.79	-5.7	0.08	4.49
Netherlands	0.27	4.59	0.33	4.45	0.8	-1.11	0.56	3.08	0.53	-0.05	0.57	2.12
Portugal	1.8	-1.46	0	14.35	1.27	3.86	0.45	3.43	1.58	4.12	0.45	4.5
Spain	1.51	3.02	-0.08	4.11	1.18	1.52	0.49	1.38	1.14	0.58	0.02	2.18
Sweden	0.68	2.07	0.2	5.16	0.31	-2.95	0.43	2.5	0.51	2.55	-0.08	3
U.K	1.3	4.39	-0.12	6.24	0.95	-2.36	0.34	3.62	1.39	1.92	0.37	3.08
United States	1.42	3.05	0.1	8.12	0.41	1.67	0.36	1.24	0.46	2.07	0.22	1.83
	Financial intermediation				Public Admin and Defence				Wholesale and Retail trade			
Austria	0.57	-1.04	0.16	3.18	0.58	1.98	0.4	1.48	0.4	-1.41	-0.3	3.31
Belgium	1.1	-1.14	-0.02	3.6	0.74	3.52	-0.16	1.5	0.51	-1.44	0.35	2.25
Finland	0.89	-1.41	-1.03	0.03	1.06	2.85	0.57	1.92	1.06	2.44	0.12	2.8
France	0.86	0.44	0.1	3.06	1.11	2.1	0.35	1.14	0.9	1.39	0.23	1.43
Germany	0.3	4.56	-0.12	7.24	0.25	0.45	0.37	1.58	0.33	-2.03	0.25	2.16
Greece	1.21	-0.24	0.8	3.49	0.94	-6.3	-0.03	3.84	1.44	6.72	0.75	3.32
Itlay	1.85	0.44	-0.18	6.67	1.47	-2.04	0.07	3.7	1.52	5.42	-0.03	1.48
Korea	1.07	3.03	-0.07	12.06	1.73	3.22	0.41	3.99	1.33	4.68	0.34	4.27
Luxembourg	-0.03	7.21	0.33	10.76	0.43	2.5	-0.18	2.85	0.51	8.62	0.1	2.47
Netherlands	0.43	1.69	0.3	5.83	0.39	3.53	0.73	1.33	0.57	0.53	0.41	2
Portugal	1.84	-0.23	0.04	11.08	0.75	-10.11	-0.42	2.1	1.71	2.67	0.49	3.64
Spain	1.52	-0.7	0.06	5.84	1.25	-0.99	0.38	1.75	1.32	1.97	0.37	2.63
Sweden	1.05	-0.65	-0.29	11.52	0.75	-0.3	0.26	2.24	0.97	-2.08	-0.02	2.61
U.K	1.14	2.41	-0.01	9.6	1.23	2.57	0.14	3.22	1.14	-3.99	0.3	2.87
United States	0.15	0.58	-0.07	4.15	0.39	3.63	-0.06	4.73	0.46	2.57	0.13	2.65

Notes:This table shows the Maximum Likelihood Estimates of the dynamic factor model (4.3) - (4.6). λ, γ are factor loading on global factor and sector specific factors respectively, ρ is autoregressive coefficient of the disturbance term and σ_ϵ denotes disturbance variance for each sector.

Table B.3: Variance decomposition of sectoral disaggregated inflation into global, sector-specific and idiosyncratic component

Country	R^2-F	R^2-S	R^2-e	R^2-F	R^2-S	R^2-e	R^2-F	R^2-S	R^2-e
	Agri, hunting, forestry and fishing			Hotels and Restaurants			Pvt h.holds with empl persons		
Austria	0	0.17	0.83	0.01	0.04	0.95	0.14	0.03	0.83
Belgium	0	0.52	0.48	0.04	0.24	0.71	0.06	0.11	0.83
Finland	0.05	0.09	0.86	0.13	0.16	0.71	0.07	0.08	0.85
France	0.01	0.48	0.51	0.17	0.01	0.82	0.15	0.03	0.82
Germany	0	0.4	0.6	0.03	0.01	0.96	0.01	0.05	0.93
Greece	0.03	0.16	0.81	0.05	0.43	0.52	0.07	0.04	0.89
Itlay	0.12	0.49	0.38	0.26	0.03	0.71	0.17	0.02	0.81
Korea	0.07	0.01	0.93	0.11	0.03	0.85	0.04	0.96	0
Luxembourg	0	0.7	0.3	0.01	0.63	0.36	0	0	1
Netherlands	0	0.4	0.6	0.01	0.01	0.97	0.09	0.03	0.88
Portugal	0.07	0.32	0.61	0.01	0.43	0.56	0.35	0.04	0.61
Spain	0.01	0.16	0.83	0.18	0.07	0.74	0.29	0.11	0.6
Sweden	0.01	0.06	0.93	0.07	0.11	0.81	0.02	0.02	0.96
U.K	0.01	0.17	0.82	0.14	0.28	0.58	0.08	0.11	0.81
United States	0	0.12	0.88	0.02	0.21	0.77	0.01	0	0.99
	Construction			Health and Social work			Real Est, Renting and Bus Activities		
Austria	0.02	0	0.98	0.03	0.02	0.95	0.09	0.01	0.89
Belgium	0.11	0.02	0.88	0.04	0.04	0.92	0.07	0.01	0.92
Finland	0.01	0.01	0.97	0.11	0.28	0.6	0.1	0	0.9
France	0.13	0.06	0.81	0.35	0	0.65	0.42	0.03	0.55
Germany	0.02	0.02	0.95	0.17	0.11	0.72	0.05	0.94	0
Greece	0.09	0.05	0.86	0.17	0.07	0.75	0.13	0.06	0.8
Itlay	0.15	0	0.84	0.2	0	0.8	0.21	0.09	0.7
Korea	0.1	0	0.9	0.03	0.01	0.97	0.08	0.01	0.91
Luxembourg	0.02	0.01	0.98	0.02	0.43	0.55	0.01	0.12	0.87
Netherlands	0.05	0	0.95	0.14	0	0.85	0.04	0.05	0.91
Portugal	0.08	0.01	0.91	0.1	0.5	0.4	0.01	0.13	0.85
Spain	0.15	0.02	0.83	0.26	0	0.74	0.51	0.01	0.48
Sweden	0.02	0	0.97	0.1	0.09	0.81	0.06	0	0.94
U.K	0.09	0.05	0.86	0.07	0.03	0.9	0.01	0	0.99
United States	0.03	0.09	0.89	0.15	0.36	0.49	0.09	0	0.91
	Education			Mining and quarrying			Total Manufacturing		
Austria	0.18	0.04	0.78	0.03	0.5	0.47	0.07	0.04	0.89
Belgium	0.15	0.12	0.73	0.02	0.21	0.77	0.01	0.28	0.7
Finland	0.06	0	0.94	0	0.02	0.98	0.06	0.7	0.25
France	0.3	0.05	0.65	0.01	0.16	0.82	0.34	0	0.66
Germany	0.07	0.03	0.9	0.02	0.19	0.78	0.04	0.14	0.82
Greece	0.08	0.06	0.86	0.03	0.09	0.88	0.04	0.03	0.93
Itlay	0.06	0.03	0.91	0.08	0.32	0.6	0.26	0.23	0.51
Korea	0.17	0.02	0.81	0.06	0.1	0.85	0.06	0	0.94
Luxembourg	0.02	0.02	0.96	0.01	0.05	0.95	0.01	0.26	0.73
Netherlands	0.04	0.11	0.85	0.01	0.56	0.43	0.01	0.55	0.44
Portugal	0.03	0.31	0.66	0.03	0.02	0.95	0.19	0	0.81
Spain	0	0.17	0.83	0.01	0.01	0.98	0.24	0.32	0.44
Sweden	0.1	0	0.9	0	0.31	0.68	0.14	0.66	0.2
U.K	0.04	0.03	0.93	0.02	0.31	0.67	0.14	0.08	0.79
United States	0	0	0.99	0.01	0.48	0.51	0.14	0.09	0.77
	Electricity, Gas and Water Supply			Other comm, Personal and S. Services			Transport, Storage and Communication		
Austria	0.02	0.22	0.75	0.07	0.02	0.91	0.03	0.47	0.51
Belgium	0.03	0.12	0.85	0.04	0.12	0.84	0.08	0.61	0.31
Finland	0.02	0.07	0.91	0.12	0.81	0.06	0.12	0.08	0.8
France	0.07	0.22	0.71	0.4	0.07	0.53	0.23	0	0.77
Germany	0.03	0.7	0.28	0.07	0.16	0.77	0.04	0.11	0.85
Greece	0.03	0.06	0.91	0.09	0.03	0.88	0.12	0.1	0.78
Itlay	0.02	0.03	0.96	0.15	0	0.85	0.06	0.77	0.17
Korea	0.01	0.01	0.98	0.16	0.06	0.78	0.16	0.05	0.79
Luxembourg	0.01	0.16	0.83	0	0.21	0.78	0.02	0.3	0.67
Netherlands	0	0.28	0.72	0.1	0.01	0.89	0.09	0	0.91
Portugal	0.02	0	0.98	0.15	0.09	0.76	0.12	0.21	0.67
Spain	0.1	0.11	0.79	0.5	0.05	0.45	0.22	0.01	0.76
Sweden	0.02	0.05	0.93	0.02	0.11	0.87	0.02	0.14	0.83
U.K	0.03	0.1	0.86	0.08	0.03	0.88	0.2	0.1	0.7
United States	0.03	0.04	0.93	0.12	0.12	0.77	0.05	0.27	0.68
	Financial intermediation			Public admin and defence			Whole sale and Retail trade		
Austria	0.03	0.12	0.85	0.17	0.05	0.78	0.01	0.02	0.97
Belgium	0.08	0.09	0.83	0.16	0.08	0.76	0.06	0.06	0.88
Finland	0.01	0.99	0	0.31	0.05	0.63	0.13	0.09	0.78
France	0.08	0.02	0.9	0.54	0.05	0.41	0.3	0.09	0.61
Germany	0	0.28	0.72	0.03	0	0.96	0.03	0.12	0.85
Greece	0.18	0.01	0.81	0.05	0.05	0.89	0.15	0.4	0.45
Itlay	0.06	0	0.94	0.15	0.01	0.85	0.28	0.45	0.27
Korea	0.01	0.06	0.93	0.21	0.02	0.77	0.1	0.15	0.75
Luxembourg	0	0.4	0.6	0.02	0.01	0.97	0.02	0.62	0.37
Netherlands	0.01	0.11	0.89	0.11	0.2	0.69	0.11	0.01	0.88
Portugal	0.03	0	0.97	0.05	0.23	0.72	0.24	0.07	0.7
Spain	0.07	0.02	0.92	0.42	0.01	0.58	0.25	0.07	0.69
Sweden	0.01	0	0.99	0.13	0	0.87	0.12	0.06	0.82
U.K	0.01	0.07	0.92	0.14	0.01	0.84	0.14	0.21	0.65
United States	0	0.02	0.98	0.01	0.01	0.98	0.03	0.11	0.86

Notes: This table shows the variance decomposition of sectoral disaggregated inflation rate based on the estimates shown in Table 1. First, second and third columns for each sector show the fraction of variance attributed to global factor F (R^2-F), sector specific factor S (R^2-S) and the idiosyncratic disturbance term e (R^2-e) respectively.

Table B.4: Sectoral disaggregated inflation: Maximum Likelihood estimates by single factor model

Country	λ	ρ	σ_ϵ	λ	ρ	σ_ϵ	λ	ρ	σ_ϵ
	Agri, hunting, forestry and fishing			Hotels and Restaurants			Pvt h.holds with empl persons		
Austria	0.04	0.09	4.91	0.07	0.14	7.19	0.09	0.3	5.68
Belgium	0.03	-0.11	2.72	0.08	0.38	4.51	0.09	0.01	4.55
Finland	0.03	0.53	1.58	0.07	0.61	3.67	0.06	0.7	3.67
France	0.05	0.24	5.02	0.09	0.33	9.62	0.11	0.04	14.62
Germany	0.03	0.09	3.34	0.08	0.81	3.53	0.12	0.05	11.1
Greece	0.02	0.07	2.84	0.06	0.42	4.6	0.05	0.21	8.4
Itlay	0.04	0.24	3.76	0.08	0.66	3.35	0.06	0.68	3.76
Korea	0.06	0.17	6.49	0.08	0	7.74	0.1	0.25	9.66
Luxembourg	0.04	0.12	2.29	0.08	0.49	4.79	0.08	0.46	3.75
Netherlands	0.03	0.53	1.56	0.07	0.41	4.58	0.06	0.68	3.97
Portugal	0.03	0.48	1.36	0.06	0.48	4.39	0.11	0.71	2.91
Spain	0.04	0.38	2.09	0.06	0.78	2.93	0.04	0.62	6.25
Sweden	0.03	-0.27	1.32	0.05	0.49	4.95	0.09	0.58	3.8
U.K	0.03	0.08	2.88	0.09	0.49	4.37	0.11	0.43	5.02
United States	0.03	-0.26	3.32	0.08	0.58	4.39	0.11	0.5	3.85
	Construction			Health and Social work			Real Est, Renting and Bus Activities		
Austria	0.03	-0.13	10.29	0.09	0.12	3.78	0.06	-0.1	6.56
Belgium	0.05	0.34	2.44	0.09	-0.23	2.77	0.07	0.54	3.33
Finland	0.04	0.43	2.24	0.07	0.22	4.29	0.07	0.41	2.91
France	0.04	0.06	3.82	0.1	-0.11	11.71	0.1	0.12	4.71
Germany	0.07	-0.23	3.63	0.12	-0.19	6.58	0.1	0.11	5.93
Greece	0.03	0.18	2.23	0.09	0.22	2.6	0.07	0.49	2.91
Itlay	0.03	0.33	2.28	0.08	0.4	3.07	0.08	0.12	2.24
Korea	0.24	0.4	22.64	0.15	0.02	8.68	0.04	-0.02	5.73
Luxembourg	0.02	0.49	2.17	0.09	-0.03	3.36	0.08	0.44	1.48
Netherlands	0.05	0.39	1.92	0.1	0.1	3.86	0.08	0.34	1.84
Portugal	0.05	-0.02	2.67	0.09	0.08	3.06	0.09	0.35	2.42
Spain	0.04	-0.03	1.98	0.07	0.44	2.44	0.07	0.54	1.42
Sweden	0.02	-0.06	2.56	0.08	-0.01	2.17	0.07	0.3	2.12
U.K	0.04	0.25	2.37	0.1	-0.37	4.95	0.08	0.06	2.2
United States	0.03	0.36	2.35	0.1	-0.07	2.37	0.09	0.32	2.79
	Education			Mining and quarrying			Total Manufacturing		
Austria	0.08	0.34	5.69	0.1	0.11	6.36	0.08	-0.03	9.63
Belgium	0.04	0.41	6.86	0.1	0.5	5.73	0.03	0.38	3.91
Finland	0.06	0.11	3.81	0.11	0.39	4.75	0.05	0.13	2.46
France	0.08	-0.01	8.63	0.11	-0.11	14.48	0.04	0.15	5.35
Germany	0.03	-0.26	11.09	0.08	-0.1	12.43	0.07	-0.3	11.58
Greece	0.07	0.28	3.09	0.1	0.03	4.39	0.05	0.43	3.67
Itlay	0.06	0.3	2.96	0.07	0.04	6.42	0.05	0.21	2.37
Korea	0.03	-0.19	13.07	0.13	0.09	8.8	0.03	0.46	13.84
Luxembourg	0.06	0.25	2.73	0.11	0.2	4.03	0.02	0.41	2.64
Netherlands	0.07	0.64	2.04	0.11	0.45	4.08	0.05	0.25	2.27
Portugal	0.09	0.09	4.94	0.08	0.12	6.53	0.02	0.49	2.7
Spain	0.04	0.21	1.89	0.09	0.11	5.24	0.04	0.27	2.67
Sweden	0.08	0.15	4.88	0.07	0.07	4.47	0.08	0.2	3.27
U.K	0.07	0.12	3.25	0.1	0.39	4.1	0.03	-0.15	3.21
United States	0.07	0.03	2.91	0.09	0.3	4.51	0.06	-0.06	2.7
	Electricity, Gas and Water Supply			Other comm, Personal and S. Services			Transport, Storage and Communication		
Austria	0.05	-0.24	6.6	0.01	0.07	8.24	0.07	-0.06	11.73
Belgium	0.06	0.31	2.78	0.03	0.03	3.95	0.06	0.59	4.08
Finland	0.07	0.25	1.93	0.03	-0.14	3.1	0.05	0.26	4.85
France	0.07	0.29	4.5	0.04	0.11	6.24	0.08	0.04	6.97
Germany	0.06	0.11	3.12	0.02	0.07	12.93	0.08	-0.06	9.79
Greece	0.07	0.16	2.49	0.02	-0.1	3.03	0.07	0.42	3.45
Itlay	0.06	0.04	1.37	0.04	0.29	4	0.07	0.16	4.14
Korea	0.07	0.16	10.6	0.03	-0.02	5.82	0.15	0.17	18.13
Luxembourg	0.07	0.33	1.39	0.01	-0.17	4.06	0.06	0.28	3.61
Netherlands	0.07	0.46	1.2	0.03	-0.11	3.09	0.08	0.18	3.35
Portugal	0.05	0.36	1.99	0.01	-0.07	4.57	0.06	0.28	3.61
Spain	0.05	0.32	0.94	0.02	-0.18	2.81	0.05	-0.08	7.55
Sweden	0.06	0.56	1.6	0.04	0.11	5.03	0.08	0.04	3.3
U.K	0.06	0.29	1.98	0.05	-0.08	5.03	0.09	0.32	3.18
United States	0.06	0.21	1.45	0.04	-0.07	3.75	0.08	0.18	3.18
	Financial intermediation			Public admin and defence			Whole sale and Retail trade		
Austria	0.01	0.09	7.23	0.02	-0.09	7.09	0	0.16	12.32
Belgium	0.02	0.64	2.14	0.02	0.79	1.88	0.03	0.62	2.46
Finland	0.02	0.28	1.87	0.01	0.85	1.87	0.01	-0.1	6.93
France	0.04	0.36	4.77	0.02	0.4	5.36	0.09	0.1	8.35
Germany	0.03	0.07	8.36	0.04	0.3	6.1	0.01	-0.07	4.2
Greece	0.02	0.14	2.25	0.01	0.27	1.99	0.04	0.05	4.24
Itlay	0.04	0.56	1.7	0.04	0.77	1.72	0.04	0.18	1.53
Korea	0.07	0.34	7.47	0.07	0.37	15.03	0.07	0.34	15.5
Luxembourg	0.02	0.45	1.44	0.05	0.56	3.09	0.03	0.38	1.35
Netherlands	0.01	0.39	1.6	0.02	0.85	1.49	0.02	-0.02	5.03
Portugal	0.02	-0.19	2.5	0.06	0.5	3.48	0.03	-0.39	3.61
Spain	0.02	0.39	1.69	0.01	0.76	1.71	0.03	-0.19	1.49
Sweden	0.02	-0.04	1.6	0.02	0.08	2.27	0.05	0.22	2.07
U.K	0.03	0.24	2.45	0.04	0.54	2.1	0.03	0.15	2.08
United States	0.02	0.14	2.25	0.04	0.39	2	0.03	0.13	2.76

Notes: This table shows the Maximum Likelihood estimates of the single factor model (4.7) - (4.9). λ is factor loading on global factor, ρ is autoregressive coefficient of the disturbance term and σ_ϵ denotes disturbance variance.

Table B.5: Variance decomposition of sectoral disaggregated inflation into global and idiosyncratic component

Country	R^2-F	R^2-e	R^2-F	R^2-e	R^2-F	$R2-e$	R^2-F	R^2-e	R^2-F	R^2-e
	Agri, Hunting, Forestry and Fishing		Electricity, Gas and Water Supply		Health and Social Work		Public admin and defence		Total Manufacturing	
Austria	0.07	0.93	0.26	0.74	0.66	0.34	0.05	0.95	0.59	0.41
Belgium	0.13	0.87	0.49	0.51	0.55	0.45	0.14	0.86	0.25	0.75
Finland	0.28	0.72	0.55	0.45	0.56	0.44	0.08	0.92	0.37	0.63
France	0.39	0.61	0.56	0.44	0.64	0.36	0.12	0.88	0.31	0.69
Germany	0.22	0.78	0.44	0.56	0.73	0.27	0.26	0.74	0.4	0.6
Greece	0.09	0.91	0.53	0.47	0.69	0.31	0.05	0.95	0.46	0.54
Itlay	0.31	0.69	0.48	0.52	0.66	0.34	0.32	0.68	0.35	0.65
Korea	0.5	0.5	0.58	0.42	0.83	0.17	0.61	0.39	0.27	0.73
Luxembourg	0.26	0.74	0.56	0.44	0.63	0.37	0.49	0.51	0.09	0.91
Netherlands	0.28	0.72	0.62	0.38	0.7	0.3	0.14	0.86	0.4	0.6
Portugal	0.21	0.79	0.42	0.58	0.65	0.35	0.56	0.44	0.13	0.87
Spain	0.3	0.7	0.37	0.63	0.57	0.43	0.06	0.94	0.27	0.73
Sweden	0.1	0.9	0.55	0.45	0.58	0.42	0.07	0.93	0.6	0.4
U.K	0.17	0.83	0.53	0.47	0.56	0.44	0.31	0.69	0.17	0.83
United States	0.1	0.9	0.48	0.52	0.67	0.33	0.3	0.7	0.45	0.55
	Construction		Financial intermediation		Mining and quarrying		Pvt h.holds with empl persons		Transport, Storage and Communication	
Austria	0.18	0.82	0.01	0.99	0.72	0.28	0.69	0.31	0.48	0.52
Belgium	0.4	0.6	0.09	0.91	0.77	0.23	0.63	0.37	0.58	0.42
Finland	0.38	0.62	0.14	0.86	0.78	0.22	0.53	0.47	0.39	0.61
France	0.28	0.72	0.36	0.64	0.68	0.32	0.74	0.26	0.61	0.39
Germany	0.45	0.55	0.2	0.8	0.54	0.46	0.76	0.24	0.59	0.41
Greece	0.15	0.85	0.11	0.89	0.69	0.31	0.41	0.59	0.62	0.38
Itlay	0.19	0.81	0.34	0.66	0.51	0.49	0.53	0.47	0.53	0.47
Korea	0.94	0.06	0.55	0.45	0.81	0.19	0.73	0.27	0.85	0.15
Luxembourg	0.16	0.84	0.14	0.86	0.75	0.25	0.67	0.33	0.53	0.47
Netherlands	0.4	0.6	0.06	0.94	0.79	0.21	0.54	0.46	0.61	0.39
Portugal	0.31	0.69	0.07	0.93	0.61	0.39	0.82	0.18	0.53	0.47
Spain	0.22	0.78	0.12	0.88	0.67	0.33	0.39	0.61	0.31	0.69
Sweden	0.09	0.91	0.09	0.91	0.56	0.44	0.73	0.27	0.59	0.41
U.K	0.28	0.72	0.21	0.79	0.75	0.25	0.77	0.23	0.71	0.29
United States	0.24	0.76	0.11	0.89	0.69	0.31	0.8	0.2	0.59	0.41
	Education		Hotels and Restaurants		Other com, Personal and S. Services		Real Est, Renting And Bus Activities		Whole sale and Retail trade	
Austria	0.65	0.35	0.57	0.43	0.02	0.98	0.38	0.62	0	1
Belgium	0.34	0.66	0.66	0.34	0.19	0.81	0.64	0.36	0.19	0.81
Finland	0.46	0.54	0.64	0.36	0.12	0.88	0.61	0.39	0.02	0.98
France	0.59	0.41	0.69	0.31	0.27	0.73	0.69	0.31	0.67	0.33
Germany	0.15	0.85	0.69	0.31	0.12	0.88	0.69	0.31	0.02	0.98
Greece	0.56	0.44	0.54	0.46	0.06	0.94	0.62	0.38	0.3	0.7
Itlay	0.5	0.5	0.67	0.33	0.27	0.73	0.6	0.4	0.27	0.73
Korea	0.12	0.88	0.59	0.41	0.18	0.82	0.23	0.77	0.59	0.41
Luxembourg	0.51	0.49	0.66	0.34	0.03	0.97	0.66	0.34	0.18	0.82
Netherlands	0.61	0.39	0.6	0.4	0.11	0.89	0.67	0.33	0.09	0.91
Portugal	0.66	0.34	0.57	0.43	0.01	0.99	0.68	0.32	0.09	0.91
Spain	0.26	0.74	0.6	0.4	0.07	0.93	0.65	0.35	0.17	0.83
Sweden	0.61	0.39	0.47	0.53	0.27	0.73	0.59	0.41	0.41	0.59
U.K	0.56	0.44	0.71	0.29	0.37	0.63	0.56	0.44	0.18	0.82
United States	0.51	0.49	0.68	0.32	0.2	0.8	0.68	0.32	0.19	0.81

Notes: This table shows the variance decomposition of sectoral disaggregated inflation rate based on the estimates in Table B.4. First and second columns for each sector show the fraction of variance of disaggregated inflation attributed to the global factor F and the idiosyncratic disturbance term e respectively.

Table B.6: Variance decomposition of sectoral inflation into global and idiosyncratic component (estimated for each sector separately)

Country	R^2-F	R^2-e	R^2-F	R^2-e	R^2-F	$R2-e$	$R2-F$	$R2-e$	$R2-F$	$R2-e$
	Agri, Hunting, Forestry and Fishing		Electricity, Gas and Water Supply		Health and Social		Public admin and defence		Total Manufacturing	
Austria	0.79	0.21	0.8	0.2	0.34	0.66	0.28	0.72	0.26	0.74
Belgium	0.97	0.03	0.66	0.34	0.22	0.78	0.32	0.68	0.3	0.7
Finland	0.79	0.21	0.85	0.15	0.56	0.44	0.6	0.4	0.89	0.11
France	0.92	0.08	0.88	0.12	0.53	0.47	0.65	0.35	0.34	0.66
Germany	0.94	0.06	0.88	0.12	0.37	0.63	0.07	0.93	0.25	0.75
Greece	0.94	0.06	0.88	0.12	0.63	0.37	0.55	0.45	0.76	0.24
Itlay	0.92	0.08	0.91	0.09	0.67	0.33	0.67	0.33	0.89	0.11
Korea	0.46	0.54	0.93	0.07	0.52	0.48	0.78	0.22	0.79	0.21
Luxembourg	0.98	0.02	0.74	0.26	0.23	0.77	0.12	0.88	0.64	0.36
Netherlands	0.92	0.08	0.86	0.14	0.2	0.8	0.2	0.8	0.3	0.7
Portugal	0.93	0.07	0.92	0.08	0.7	0.3	0.46	0.54	0.77	0.23
Spain	0.92	0.08	0.9	0.1	0.61	0.39	0.67	0.33	0.83	0.17
Sweden	0.94	0.06	0.72	0.28	0.39	0.61	0.38	0.62	0.9	0.1
U.K	0.97	0.03	0.89	0.11	0.58	0.42	0.61	0.39	0.78	0.22
United States	0.93	0.07	0.91	0.09	0.31	0.69	0.14	0.86	0.68	0.32
	Construction		Financial intermediation		Mining and quarrying		Pvt h.holds with empl persons		Transport, Storage and Communication	
Austria	0.11	0.89	0.11	0.89	0.93	0.07	0.12	0.88	0.35	0.65
Belgium	0.33	0.67	0.27	0.73	0.99	0.01	0.19	0.81	0.49	0.51
Finland	0.32	0.68	0.07	0.93	0.74	0.26	0.51	0.49	0.69	0.31
France	0.44	0.56	0.26	0.74	0.95	0.05	0.29	0.71	0.66	0.34
Germany	0.15	0.85	0.09	0.91	0.94	0.06	0.04	0.96	0.34	0.66
Greece	0.68	0.32	0.61	0.39	0.94	0.06	0.44	0.56	0.83	0.17
Itlay	0.57	0.43	0.53	0.47	0.98	0.02	0.53	0.47	0.66	0.34
Korea	0.77	0.23	0.27	0.73	0.97	0.03	0.41	0.59	0.86	0.14
Luxembourg	0.18	0.82	0.03	0.97	0.69	0.31	0	1	0.45	0.55
Netherlands	0.18	0.82	0.21	0.79	0.99	0.01	0.43	0.57	0.34	0.66
Portugal	0.59	0.41	0.6	0.4	0.93	0.07	0.65	0.35	0.87	0.13
Spain	0.64	0.36	0.51	0.49	0.21	0.79	0.53	0.47	0.67	0.33
Sweden	0.26	0.74	0.26	0.74	0.98	0.02	0.12	0.88	0.29	0.71
U.K	0.59	0.41	0.36	0.64	0.99	0.01	0.36	0.64	0.84	0.16
United States	0.23	0.77	0.01	0.99	0.99	0.01	0.03	0.97	0.33	0.67
	Education		Hotels and Restaurants		Other com, Personal and S. Services		Real Est, Renting And Bus Activities		Whole sale and Retail trade	
Austria	0.35	0.65	0.13	0.87	0.28	0.72	0.2	0.8	0.16	0.84
Belgium	0.45	0.55	0.2	0.8	0.09	0.91	0.15	0.85	0.29	0.71
Finland	0.47	0.53	0.63	0.37	0.51	0.49	0.18	0.82	0.69	0.31
France	0.85	0.15	0.58	0.42	0.62	0.38	0.32	0.68	0.64	0.36
Germany	0.2	0.8	0.15	0.85	0.12	0.88	0.11	0.89	0.14	0.86
Greece	0.65	0.35	0.44	0.56	0.69	0.31	0.5	0.5	0.84	0.16
Itlay	0.35	0.65	0.73	0.27	0.59	0.41	0.47	0.53	0.8	0.2
Korea	0.82	0.18	0.72	0.28	0.75	0.25	0.53	0.47	0.82	0.18
Luxembourg	0.17	0.83	0.04	0.96	0.03	0.97	0.05	0.95	0.35	0.65
Netherlands	0.38	0.62	0.05	0.95	0.48	0.52	0.09	0.91	0.37	0.63
Portugal	0.25	0.75	0.62	0.38	0.66	0.34	0.29	0.71	0.89	0.11
Spain	0.35	0.65	0.71	0.29	0.67	0.33	0.57	0.43	0.79	0.21
Sweden	0.42	0.58	0.63	0.37	0.18	0.82	0.21	0.79	0.57	0.43
U.K	0.48	0.52	0.69	0.31	0.5	0.5	0.22	0.78	0.67	0.33
United States	0.1	0.9	0.36	0.64	0.17	0.83	0.12	0.88	0.31	0.69

Notes: This table shows variance decomposition of sectoral disaggregated inflation rate estimated for each sectors across countries separately. First and second column for each sector show the fraction of variance attributed to global factor F and the idiosyncratic disturbance e respectively.

Chapter 5

Monetary Policy Reaction Function for the United States and the United Kingdom: A Global Perspective

5.1 Introduction

In recent years, the impact of globalization on monetary policy formulation has become one of the central topics in international macroeconomics literature. The literature on influence of globalization on monetary policy has generally focused on whether the sensitivity of inflation has declined to domestic output gap and increased to foreign output gap due to globalization.[1] Moreover, whether the lower inflation rates are

[1]This hypothesis is tested by estimating Philips Curve with the argument that globalization has flatten the Philips Curve. A flatter Philips Curve implies that the sensitivity of domestic inflation has decreased to domestic output gap. Globalization may lead to flattening of Philips Curve due to increased competitive pressures, increased flow of foreign investments and trade, increased supply of global labour and disciplinary effect of globalization on monetary policy (see chapter 2 for detailed discussion).

due to lower import prices and increased competitive pressures or better monetary policy rules. Since the Global Financial Crisis of 2007-2009, the literature, focusing on globalization of financial markets and its impacts on the monetary policy has expanded rapidly (see, Kamin (2010), Spiegel (2009)and Meier (2012) for example).

It is generally believed in the literature that globalization has been an important factor in promoting economic growth and the economies in the world have become highly sensitive to international developments (For example, see Bernanke (2007), Rogoff (2006), Fisher (2008) and White (2008) among many others). A more competitive environment has been promoted by the global developments. The behaviour of macroeconomic variables is altered by the integration of global product, factor and financial markets. Consequently the task of monetary policy has become complicated and challenging. However, the debate regarding what ways, and to what extent, the globalization has influenced monetary policy is not yet settled. Globalization is considered as an important factor in lowering the level and volatility of inflation since the 1990s. The greater integration of goods, factor and capital markets across the world has been eroding the ability of central banks to accomplish their main task i.e. controlling inflation within their national borders. While, others argue that the effects of globalization on inflation and monetary policy are exaggerated as the claim that globalization has been an important factor in reducing inflation does not hold up in recent years. They challenge the view of proponents of globalization that central banks are losing their control in accomplishing their objectives in the global world. As Michael Woodford (2010) states,

"*I find it difficult to construct scenarios under which globalization would interfere in any substantial way with the ability of domestic monetary policy to maintain control over the dynamics of domestic inflation*" (p.14).

Inflation movements in many industrial countries after the collapse of Bretton Wood system were observed to be very similar with comparable standard deviations. Taylor (2008) reviews the history of the impact of globalization on monetary policy thought and practice and states, "*out of this experience (of great inflation in 1970s) came better monetary theories, better monetary policies and of course better macroeconomic results. The theories and policies were designed for, or at least influenced by, a certain conceptualization of globalization. Empirical models to evaluate monetary policy moved rapidly in a global direction*" (p.257).

The fact that monetary policy has been dealing with globalization is documented by Clarida et al. (1998) where they estimate monetary policy reaction function for Germany, Japan, the U.S. the U.K. France and Italy. To test the effect of global variables on domestic monetary policy, they estimate the forward looking Taylor Rule augmented with real exchange rates, foreign interest rates and the money supply. They find that German monetary policy has a large and significant effect on the monetary policies of the U.K., France and Italy.

Thus monetary policy of a country in an international setting should consider the output gap and inflation or interest rate set by the central banks of other countries especially of the major trading partners with domestic inflation and output gap. This setting is recommended by a simple Taylor Rule augmented with foreign variables of interest (e.g. foreign interest rate, foreign output gap and exchange rate). This paper is aimed at examining whether domestic monetary policy reaction functions are influenced by global variables. Our paper contributes to the existing literature by estimating variants of the Taylor Rule in an international setting with global inflation and output gap. We computed global inflation and global output gap for the United States and the United Kingdom and find that the global measures of inflation and output gap are highly correlated with domestic inflation and output gap. To disentangle the domestic inflation and output gap from global effects we regress domestic inflation and output gap on the global inflation and output gap. The residuals obtained from this regression are used as the component of domestic inflation and output gap that is not related to the global variations. Then we estimate a forward-looking policy reaction function for the United States and the United Kingdom with the domestic, global and residual inflation and output gaps. Moreover, we augmented policy reaction function with foreign variables such as real effective exchange rate and foreign interest rate.

We find strong empirical evidence that the policy makers at the Federal Reserve and Bank of England consider the international factors while conducting the monetary policy. For a sample period from 1985-2010, we find that the Federal Reserve responds to global inflation, the country specific output gap and global output gap while the country specific inflation appeared as insignificant. Moreover, the Federal Reserve is more concerned about the medium and long term variation in inflation and does not follow the Taylor principle when responding very short term variation in inflation.[2] The Bank of England strongly responds to global and domestic variables and contrary to the Federal Reserve, takes into account the short term variations in inflation as well. This may be due to the Inflation Targeting Framework of monetary policy. Moreover, we find that the Central Banks also take into account the foreign variables such as real effective exchange rate and foreign interest rate while setting policy rate. Similar results are obtained when we estimated reaction function using the inflation measure based on CPI. However, contrary to the full sample estimation in sub sample estimation of the reaction function (Greenspan-Bernanke era), the Federal Reserve respond to country specific inflation as well as global inflation whereas global output gap becomes insignificant. This implies that the Federal Reserve focused on price stability in Greenspan-Bernanke era.

The rest of the chapter is set out as follows. Section 5.2 reviews the related literature. Section 5.3 explains our data set, preliminary analysis and econometric techniques. Section 5.4 presents and discusses the empirical results. Section 5.5 provides some robustness checks and Section 5.6 concludes and summarises our findings.

5.2 Review of Literature

The literature on monetary policy rules for closed economies is vast. The most popular simple monetary policy rule for closed economy is due to Taylor (1993). Under the original Taylor Rule, the policy interest rate varies in response to inflation and the output gap. Since then we see enormous literature on comparisons of the Taylor Rules

[2]The Taylor principle is that nominal interest rate should respond strongly to inflation increases i.e. an increase in nominal interest rate in response to increase in inflation must be larger than the rise in inflation.

that are backward- and forward-looking, rules that include or exclude interest rate smoothing terms and finally the rules with different measures of inflation and output gap. It also contains the historical analysis of monetary policy rules for various countries. Ball (1999a), for example, shows that optimal monetary policy rule for a closed economy can be expressed as a backward-looking reaction function. More recently, the literature is focused on forward looking policy rules where the interest rate varies in response to expected inflation and the output gap.[3] Svensson (1997) argue that in the forward-looking optimal policy rules, the inflation forecast performs the role of intermediate target. The forward-looking rule was first empirically estimated by Clarida et al. (1998) while Batini and Haldane (1999) analytically examined them and concluded that inflation-forecast based rules are superior to backward-looking specifications in terms of welfare.

The Taylor Rule is also employed in open economy context. The main alternative open economy policy rule to Taylor Rule is developed by Ball (1999b). He argues that Taylor Rule performs poorly in open economies unless it is modified as it is originally designed for closed economy. He extends the Svensson's closed economy model to an open economy setting and assess how the optimal policies change in open economies. He derives an optimal instrument rule from three open economy equations. A dynamic open economy IS equation, where output depends on lags of itself, the real interest rate and the real exchange rate; the open economy Phillips curve where the change in inflation depends on lagged inflation and lagged changes in exchange rate (which affects inflation through import prices) and the equation establishing the relationship between interest rate and exchange rate that captures the behaviour of asset market. His optimal instrument rule differs from the Taylor Rule in a closed economy in two ways. First, the policy instrument is a weighted sum of the interest rate and the exchange rate (a monetary condition Index). Secondly, on the right hand side of the policy rule, inflation is replaced by long run inflation which is a measure of inflation adjusted for the temporary effects of exchange rate fluctuations. Hence, the Ball (1999b)s open economy policy rule is MCI (Monetary condition Index) based. A Monetary Condition Index is a weighted average of the domestic interest rate and

[3]See for example Clarida et al. (1998, 2000), Orphanides (2001) and Svensson (2003) among others.

the (log) exchange rate which are often used to measure the stance of the monetary policy in an open economy. However, MCIs are theoretically and empirically criticized in literature (see for example Batini and Turnbull (2000) and Batini et al. (2003)). One constructional flaw of MCI based rule is that it makes difficult the identification of exchange rate shock because it focuses on aggregated exchange rate and interest rate instead of focusing movements in exchange rate and interest rate in isolation. Thus the performance of the MCI based rules depends on the nature of the shocks. It may perform poorly in the face of the shocks that affect the exchange rate but do not ask for a compensating change in interest rates and thus may not be used as a guidance policy rule (Batini et al. (2003)).

Batini et al. (2003) modify Ball's closed and open economy rules. They estimated a policy rule for a small open economy like the United Kingdom using a two sector open economy dynamic stochastic general equilibrium model. They evaluated and compared the performance of simple monetary policy rule i.e. the Taylor Rule, inflation-forecast based rule, a nave MCI based rule, Ball (1999b) and a family of alternative 'open economy' rules in their model setting. To account for the openness of the economies, they consider four different rules, three of which are variants of Ball (1999b)[4] open economies rules. First they augment the Ball (1999b) rule with a balance of trade term. Second, they replace the aggregate output with output gaps in two sectors (exports and non-traded). In the third variant they use the Ball (1999b) rule with a restriction on the contemporaneous and lagged exchange rate terms so that their coefficients are equal and opposite implying that policy makers respond to the changes in real exchange rate rather than levels. The fourth rule is a modification of inflation forecast based rule of Batini and Haldane (1999) by adding lagged and current real exchange rate terms. They conclude that an inflation forecast based rule (a rule that reacts to deviations of expected inflation from target) performs best as it appears quite robust to different shocks and is associated with a lower than average variability of inflation when compared to alternative rules.

Svensson (2003) investigates open economy issues in a forward-looking framework

[4]They re-arrange the Ball (1999b)'s rule so that it resembles Taylor Rule augmented with contemporaneous and lagged real exchange rate terms.

which includes foreign variables such as foreign exchange risk premium, real exchange rate and foreign interest rate (modeled as determined by a Taylor-type Rule). He derives an optimal rule for the domestic interest rate which includes one or most of these foreign variables. Kirsanova et al. (2006) show that in a model with Uncovered Interest rate Parity (UIP) shocks, reaction function can be written as including the exchange rate gap term. Adam et al. (2005) estimate the Taylor Rule for U.K. augmented with U.S. and German interest rate for pre ERM (1985-1990) era, post ERM era (1992-1997) and the era of Monetary Policy committee (1997-2003). They conclude that U.S. and German interest rate can be clearly included in U.K. monetary policy reaction function and domestic variables have no contribution in the pre-ERM period and only a weak contribution at best in the post ERM period. However, Clarida et al. (2001) conclude that optimal monetary policy should have the same form for an open economy as for a closed economy. Monetary policy should not respond to foreign interest rate or exchange rate. Taylor (2008) argues that moving interest rate in response to inflation or expected inflation already includes an indirect response to exchange rate movement as depreciation of the exchange rate increases inflation. He stresses that reacting directly to exchange rate will cause "herky-jerky" movements in the interest rate which is harmful for the economy. Similar is the argument of Monetary Policy Committee, "it would not be sensible for policy to react to high frequency movements in the exchange rate, as it could lead to a volatile path of interest rates from month to month, and might make it more difficult for others to understand the motives for interest rate changes." Similar discussion and conclusion is given by Mishkin (1995). They argue that central banks should consider the effects of exchange rate fluctuation on inflation and output gap rather than an independent role of exchange rate when implementing monetary policy. However, the existing empirical literature provides evidence that Central Banks do take exchange rate behaviour into account while conducting monetary policy although they do not openly recognize it. The role of exchange rate in Inflation Targeting countries is investigated by Edwards (2006). They find that Inflation Targeting countries with a history of high and unstable inflation tend to take into account the fluctuation in nominal exchange rate when undertaking monetary policy.

A number of specification and estimation issues are raised in literature on the Taylor

Rule estimations for closed or open economies. Inference from the estimates of the Taylor Rule is sensitive to these issues. First issues concerns including the interest rate smoothing term in the Taylor Rule. The original Taylor Rule does not include the lagged interest rate term. However, most of the empirical research later concludes that to allow for interest rate persistence or smoothing behaviour on the part of central bank, lagged dependant variable is included in the Taylor Rule regression.[5] The second issue is regarding the weights embedded in inflation and output gap. In the original Taylor Rule weight of 0.5 is specified on output gap while in theoretical research, Ball (1999a) and Rudebusch and Sevensson (1999) argue for a higher than 0.5 weight on output gap. On the other hand Rotemberg and Woodford (1999) and Woodford (2010) argue for a smaller response to output gap. However, empirically it is found that the Federal reserve has reacted differently to output gap over time.[6] The issue, whether the policy reaction function satisfies the Taylor principle[7] is extensively discussed by Clarida et al. (1998) and Taylor (2008). Clarida et al. (1998, 2000), Adam et al. (2005) and Hayo and Hofmann (2006) report weights well above unity on inflation for U.S., U.K. and E.C.B.(European Central Bank) respectively. However, Clarida et al. (2000) produce weight of less than one (0.83) for Pre-Volker period in U.S. suggesting that estimates are sensitive to the estimation sample period. For open economy Taylor Rule, Clarida et al. (1998) found that when they added German interest rate to their baseline reaction function for France, Italy and U.K. the weight on inflation fell from around one to 0.5. Ball (1999b) found that the coefficient on inflation in his open economy model should not differ substantially from that in his closed economy model (Ball (1999a)).

Thirdly different measures of output gap and inflation are used while estimating the Taylor Rule. Kozicki (1999) uses different measures of output gap and inflation to estimate the Taylor Rule and shows that results are not robust across different measures. Fourthly an issue concerns the timing of economic variables on which interest

[5] See for example Clarida et al. (1998), Goodhart (1999), Sack (1998, 2000), Sack and Wieland (2000),Collins and Siklos (2004) and English et al. (2003).

[6] For example for post 1979 period, Clarida et al. (2000) report a coefficient of 0.93, Kozicki (1999) reports different weights with different specifications of Taylor Rule for 1983-1997.

[7] Taylor principle is a key characteristic of the Taylor Rule which states that to maintain price stability, the nominal interest rate should rise more than one for one with an increase in inflation above target i.e. the coefficient on inflation in the Taylor Rule must be larger than one. Failure to stick to the Taylor principle results in drop of real interest rate and consequently spiral of high inflation.

rate setting depends, i.e. use of current versus real time data. The policy makers take decisions on the basis of information that is available to them at that time while output data is revised at later dates. Most of the empirical work is based on revised data. In recent literature, the Taylor Rules are estimated using real time data.[8] Molodtsove et al. (2008) estimated the Taylor Rule for the U.S. and Germany and find that there is a small difference between the estimates of the Taylor Rule obtained from revised and real time data for U.S. However, the German policy rule satisfies the Taylor principle only when estimated using real time data. Despite the issues described above which are not exhaustive, Taylor Rule is generally accepted as a simple and useful guideline for monetary policy.

The most influential empirical work on Taylor Rule is due to Clarida et al. (1998). They estimate the forward-looking Taylor Rule for the U.S. Germany, Japan, France, Italy and U.K. They provide evidence of foreign influences on France, Italy, Japan and the U.K. monetary policies and show that interest rates in France, Italy and the U.K. were much higher than warranted by domestic macroeconomic conditions at the time of EMS collapse. We follow their approach and investigate the global influences on reaction function of the United States and the U.K.

5.3 Data, Summary Statistics and Econometric Analysis

5.3.1 Data

In empirical work, we estimate Taylor's Rule for the United States and the United Kingdom. We use quarterly data on domestic output gap, inflation, interest rate, real exchange rate, global inflation and global output gap for the U.S. and the U.K. The quarterly data is obtained from web sites of the I.M.F. International Financial Statistics E.S.D.S. International, the Bank of England and the Federal Reserve Bank of Philadelphia over a time period of 1985-2010. Our sample period starts from 1985 because the data on inflation expectation for U.K is available since 1985. This is the

[8]See for example Adema (2004), Gerdesmeier and Roffia (2004) and Molodtsove et al. (2008).

year when the monetary policy regime of targeting broad money (M3) was officially abandoned. To make the comparison, we choose the same sample period for the U.S. as well. We use the 'Federal Fund Rate' for the U.S. and overnight interbank lending rate for the U.K. as short term nominal interest rate.[9] Domestic output gap for the U.S. and the U.K. is measured as the log of seasonally adjusted real Gross Domestic Product, de-trended using the Hodrick-Prescott filter ($\lambda = 1600$).[10] Considering the discussion in literature on the Taylor Rules regarding the choice of inflation measure, we used three alternative measures of inflation i.e. GDP price inflation, CPI inflation and expected inflation.[11] GDP price inflation and CPI inflation for the United States and the U.K. is computed by

$$\pi_t = 100 \times \ln(\frac{P_t}{P_{t-4}}) \tag{5.1}$$

where $P = GDP$ deflator or CPI

The expected inflation is measured as four year implied inflation forward rate expectation for the U.K.[12] The implied inflation forward rate is constructed using data on nominal and real forward interest rate. These are computed using returns on nominal (conventional U.K. gilt-edged securities) and real (UK index-linked gilts) bonds of various maturities.[13] We used four year implied inflation forward rate because the data on implied inflation forward rate for 2.50, 3.00 and 3.50 years has missing information. Gefang et al. (2011) also used four year implied inflation forward rate as a measure of inflation expectation. The inflation expectation for the U.S. is measured as one-year-ahead inflation forecasts from the survey of professional forecasters.[14]

[9] The 'Federal Fund Rate' is reasonable to use as a monetary policy instrument for the United States and an inter bank lending rate for the United Kingdom. These interest rates are used by Clarida et al. (2000) to estimate the Taylor Rules for the U.S. and the U.K. Mehra and Sawhney (2010) also use the Federal Fund Rate for U.S.

[10] Hodrick-Prescott filter is the most widely used statistical measure of output gap. Some other commonly used statistical methods to measure output gap are linear de-trending, Beveridge Nelson decomposition, Unobservable component method and Band-Pass filter.

[11] We used alternate measures of inflation for robustness check of our results as the Taylor Rule recommendation across alternate measures of inflation are not robust for United States. See for example Kozicki (1999). The results based on CPI and expected inflation are given in Appendix C.

[12] The data is available at http://www.bankofengland.co.uk/statistics/yieldcurve/archive.htm.

[13] Implied inflation rate is computed by the data on conventional gilt-edged securities and index-linked gilts using Fisher relationship. As the index-linked gilts allow us to obtain real interest rates and from conventional gilts we can get nominal interest rates. The nominal interest rate embody the real interest rate and a compensation for the erosion of the value of investment because of inflation. See Bank of England for the details.

[14] The data is available at http://www.philadelphiafed.org/research-and-data/real-time-center/survey-of-professional forecasters/historical-data/inflation-forecasts.cfm.

To compute a measure of global output and inflation for the U.S. and the U.K., we identified their twenty largest trading partner countries.[15] We use quarterly data on their GDP, GDP and CPI inflation (computed by year-on-year percentage changes in GDP deflator and consumer Price index) and their exports and imports with the U.S. and the U.K. over the sample period. We seasonally adjusted the variables where already seasonally adjusted variables were not available (using Census-X12 method). For each country, we computed the output gap using Hodrick-Prescot filter. The global output gap (y_t^G) is then measured as the weighted average of the countries output gaps (y_t^i), where the weights (w^i) are given as the sum of exports and imports of country i with the U.S. (the U.K.) as a fraction of total U.S.(U.K.) exports and imports with the set of countries in period t. Borio and Filardo (2007) and Ihrig et al. (2007) also used the similar measure of global output gap.[16]

$$y_t^G = \sum_{i=1}^{N} w_t^i y_t^i \tag{5.2}$$

Where $i = 1, ...N$ is an index of different countries and weight is given by:

$$w_t^i = \frac{(Imprts_t^i + Exports_t^i)}{TotalImports_t + TotalExports_t} \tag{5.3}$$

We then computed the global inflation for the U.S. and the U.K. as the weighted average of the trading partner's inflation rate, where the weights are given as in Equation 5.3. The depreciation rate of real exchange rate for the United States and the U.K. is computed as the percentage change in trade weighted real exchange rate index (REER based on REL.CP).

[15] We initially identified forty largest trading partners of U.K and U.S. however the data was not available for all the countries. Therefore, the countries with missing data were dropped from the analysis and we are left with twenty partners for both, the U.S. and the U.K. they are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hongkong, Italy, Japan, Korea, Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland and UK for U.S. and U.S. for U.K.

[16] Borio and Filardo (2007) used a changing weighted average of the top 10 trading partners whereas Ihrig et al. (2007) considered the top 35 trading partners.

5.3.2 Descriptive Statistics

Figures 5.1 and 5.2 show the movements of domestic and the global inflation and output gap with the interest rates for the United States and United Kingdom. Figure 5.1 depicts the responsiveness of the federal fund rate to the U.S. inflation, out put gap and global inflation and output gap over the time period 1985-2010. From 1985 to late 1987, we observe a loose monetary policy to avert deflationary pressures. In October 1987, Greenspan became the chairman of the Federal Reserve. He tightened monetary policy in response to increasing inflation and raised the interest rate from 6.9 percent in late 1987 to 9.7 percent in mid 1989. This episode is followed by a phase of recession 1990-1992. The Fed responded to the recession by lowering interest rate to almost 3 percent in late 1992 and it was kept at around 3 percent until spring 1994. In 1994-1995 the Fed increased the interest rate from 3.21 percent in 1994 to 6.02 percent in mid 1995 though the inflation rate remains fairly stable at around 2 percent. The interest rate was increased because the Fed officials feared that the stock market boom (1994-2000) would cause rapid growth in spending and inflation (Bordo and Wheelock (2007)). The interest rate was hardly changed from 6 percent in late 1995 to about 5 percent in late 1998. The Fed lowered the interest rate in response to the Russian bond default and LTCM (Long-Term Capital Management) failure in late 1998 and increased again in 1999 to evade rising inflation as stock market boom started in 1994 was not over yet and output gap was also rising.

The next episode of lowering interest rate started after the burst of dotcom-bubble in late 2000. Thus in response to 2001 recession federal fund rate was decreased from 6.5 percent in late 2000 to 1.75 percent in December 2001 and to 1 percent in 2003 where it stayed almost for a year. In 2004, the Fed again adopted the tight monetary policy as the economy was heating up because of the housing boom. The interest rate increased from almost 1 percent in 2004 to 5.25 percent in 2006 and stayed at almost 5 percent for a year until the beginning of financial crisis in late 2007. To combat the recession the Fed lowered the interest rate to near zero percent. The historical low interest rate during the time periods 2002-mid 2005 and late 2008-2010 resulted in negative real fund rate.

Figure 5.2 depicts the monetary history of the U.K. over 1985-2010. Five distinguishable phases can be identified in the U.K monetary policy. First phase represents the period from 1985-mid-1988 when interest rate follows a downward trend with considerable oscillation around this trend. In the second phase the interest rate increased from 7.35 percent in mid-1988 to 15.04 percent in mid-1990 followed by a phase of loose monetary policy until early 1993. These three phases of monetary policy comprise the monetary policy regime (1985-1992) when Bank of England was targeting exchange rate in various forms. Before joining the Exchange Rate Mechanism (ERM) in September 1990, the United Kingdom was following German monetary policy with an aim to stabilise exchange rate movements (Lildholdt and Wetherilt 2004). During the membership period of ERM (1990-1992), easy monetary policy was adopted to combat the recession resulted from tight monetary policy during 1988-1990. In September 1992, England left the ERM and adopted the framework of inflation targeting which was followed by further decrease in interest rate. The fourth phase covers the period, 1993 - late 2008 when the interest rate hovers around a range of 3.35 percent to 7.35 percent with successively lower peaks and troughs. The final phase started in late 2008 when interest rate declined from 5.5 percent to almost 0.50 percent in 2010 to bring the economy out of recession followed by the worldwide financial crisis.

It is interesting to note in Figure 5.1 and 5.2 that the dynamics of domestic inflation and output gap are quite similar with the dynamics of global inflation and output gap respectively in both countries. This can be more clearly observed in Figure 5.3 and 5.4. The coefficient of correlation between the U.K. inflation and global inflation is 0.75 and for the U.K. and global output gap it is 0.59. The correlation between domestic and global variables for the United States is even higher than the U.K. (the co-efficient of correlation between U.S. and global inflation and output gap is 0.77 and 0.72 respectively). The comparison of summary statistics of the U.S. and the U.K. shows that interest rate and inflation in the U.K. is higher than in the United States on average. Similar is the case with volatility. The domestic and global output gap and global inflation for both countries is almost same due to the fact that these measures are computed as weighted average of output gap and inflation of their trading partners which are nearly common for both economies.

5.3.3 Taylor Rule Estimation

We use the Taylor Rule to estimate the policy reaction function of the United States and the United Kingdom. The Taylor Rule is a linear algebraic rule that specifies how a central bank should respond to deviations of inflation and output from their targets. We follow Clarida et al. (1998) and estimate the following forward looking Taylor Rule as a baseline case.

$$r_t^* = \bar{r} + \beta(E[\pi_{t+k}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t]) \tag{5.4}$$

Where, $\bar{r}$ is the long run equilibrium nominal rate of interest, π_{t+k} is the inflation expectation between periods t and t+k, π^* is the target rate of inflation, y_t is a measure of output gap.

Considering the implied target for the ex ante real interest rate, $rr_t \equiv r_t - \pi_{t+k}$. Rearranging equation 5.4 yields;

$$rr_t^* = \bar{rr} + (\beta - 1)(E[\pi_{t+k}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t]) \tag{5.5}$$

Where, $\bar{rr}$ is the long run equilibrium real rate of interest. The estimate of the magnitude of parameter β provides important information to evaluate a policy rule of a central bank. If β is greater than 1, the target real rate adjusts to stabilize inflation and output (given γ is greater than zero). However, if β is less than 1, the target rate moves to accommodate changes in inflation which may cause self-fulfilling bursts of inflation and output gap (Clarida et al. (1998)). The Taylor Rule specified in Equation 5.4 are modified in literature by incorporating the interest rate smoothing term to capture the tendency of central banks to smooth changes in interest rate.[17] Thus the actual rate is partially adjusted to the target as follows:

$$r_t = (1 - \rho)r_t^* + \rho r_{t-1} + \upsilon_t \tag{5.6}$$

[17]Incorporation of smoothing term in the Taylor Rule refers to include the lagged interest rates because effectively current interest rates are highly correlated to previous period rates. Central Banks tend to smooth changes in interest rate potentially due to fear of loss of credibility from sudden large policy changes and fear of disrupting capital markets etc. if Central Banks do not smooth interest rate changes, the policy rates would be very volatile. See Goodfriend (1991), Clarida et al. (1998), Sack (1998), Sack and Wieland (2000), Collins and Siklos (2004) and Goodhart (1999) for detailed discussion on theoretical and practical importance of interest rate smoothing by a central bank.

Where, ρ captures the degree of interest rate smoothing and υ_t is *i.i.d.*, an exogenous random shock to the interest rate.

To estimate Equation 5.4, we define $c \equiv \bar{a} - \beta\pi^*$ and rewrite Equation 5.4 as

$$r_t^* = c + \beta E[\pi_{t+k}|\Omega_t] + \gamma E[y_t|\Omega_t] \tag{5.7}$$

Incorporating the partial adjustment mechanism in the target model 5.7, we get

$$r_t = (1-\rho)(c + \beta E[\pi_{t+k}|\Omega_t] + \gamma E[y_t|\Omega_t]) + \rho r_{t-1} + \upsilon_t \tag{5.8}$$

Rewriting the rule in terms of realized variables yields

$$r_t = (1-\rho)c + (1-\rho)\beta\pi_{t+k} + (1-\rho)\gamma y_t + \rho r_{t-1} + \varepsilon_t \tag{5.9}$$

Where, the error term,

$$\varepsilon_t \equiv -(1-\rho)\beta\pi_{t+k} - E[\pi_{t+k}|\Omega_t] + \gamma(y_t - E[y_t|\Omega_t]) + \upsilon_t$$

is a linear combination of the forecast errors of inflation and output and the exogenous disturbance, υ_t. We assume a vector z_t of variables (that are orthogonal to error term) within the central bank's information set at time t it chooses the interest rate. We estimated the baseline model specified in Equation 5.9 using Generalized Method of Moments (G.M.M.). G.M.M. is a preferred estimation technique as it takes into account the possible correlation between independent variables and the residuals (so-called simultaneity bias) by using the appropriate instruments.[18] The set of instruments contains the variables known to the central bank at the time it sets the interest rate. The variables in instruments set should be orthogonal to the error term. In this context, we used the lagged explanatory variables and lagged interest rate as instruments. The weighting matrix is used as suggested by Newey and West (1987), who propose a general covariance estimator that is consistent in the presence of both heteroskedasticity and autocorrelation of unknown form (HAC). The G.M.M. estimation is also preferred to O.L.S. as it does not require information about the exact distribution of the error term which implies that the normality assumption is not required (a crucial assumption in

[18]See Hansen (1982) and Wooldridge (2001) for a discussion of G.M.M.

OLS). Our instrument set includes lagged values of interest rate, inflation, output gap. The appropriateness of instruments choice is tested with j-statistics (as explained in Clarida et al. (1998)).

After estimating conventional rules, we proceed to estimate the Taylor Rule augmented with global variables. We estimate the Taylor Rule with global inflation and out put gap. The importance of global inflation and output gap for monetary policy is emphasized by Bullard (2012). However, we observe a high degree of correlation between global and domestic variables (as noticed in Figures 5.3 and 5.4). Because of the high correlation between the global and domestic variables, the global variables cannot be incorporated in baseline reaction function with domestic variables. Thus, to avoid multicollinearity, we estimate the baseline policy rule with domestic variables (Equation 5.9) and then with the global variables as follows:

$$r_t = (1-\rho)c + (1-\rho)\beta^G \pi^G_{t+k} + (1-\rho)\gamma^G y^G_t + \rho r_{t-1} + \varepsilon_t \tag{5.10}$$

Where, the variables π^G_{t+k} and y^G_t are global inflation and output gap respectively. It is however, important to note that as dynamics of the global and domestic variables are quite similar, the reaction of monetary policy to global and domestic variables cannot be clearly differentiated. To incorporate domestic and global variables in a policy reaction function, we obtain the component of domestic inflation (and output gap) that is not related to global inflation (and output gap) by regressing the domestic inflation (output gap) on global inflation (output gap). The following simple regressions are run to obtain the residuals:

$$\pi_t = c + \alpha_1 \pi^G_t + \mu_{\pi,t} \tag{5.11}$$

$$y_t = c + \alpha_2 y^G_t + \mu_{y,t} \tag{5.12}$$

Where, π_t, y_t are domestic inflation and output gap and π^G_t, y^G_t are global inflation and output gap computed as explained in section 3.1. The residuals $\hat{\mu}_{\pi,t}$ and $\hat{\mu}_{y,t}$ represent the domestic inflation and output gap that are not correlated with the global inflation and output gap. The Taylor Rule is then estimated with the residuals obtained from

Equation 5.11 and Equation 5.12 as follows:

$$r_t = (1-\rho)c + (1-\rho)\beta^{Res}\hat{\mu}_{\pi,t+k} + (1-\rho)\gamma^{Res}\hat{\mu}_{y,t} + \rho r_{t-1} + \varepsilon_t \qquad (5.13)$$

The Equation 5.13 is estimated using G.M.M. with instrument set that contains lagged values of interest rate, residuals of inflation and output gap. This is a representation of reaction function that incorporates domestic inflation and output gap, not related to the global inflation and output (country specific inflation and output gap hereafter). As inflation and output gap in Equation 5.13 are disentangled from global shocks, the influence of global developments on domestic monetary policy can be assessed by comparing the estimates obtained from Equation 5.9 with those of Equation 5.13. If the estimated parameters obtained from Equation 5.9 are different from those obtained from Equation 5.13, we could infer that global developments influence domestic monetary policy and vice versa.

Moreover, we then incorporate the global variables in Equation 5.13 and estimate the following reaction function;

$$r_t = (1-\rho)c+(1-\rho)\beta^G\pi^G_{t+k}+(1-\rho)\gamma^G y^G_t+(1-\rho)\beta^{Res}\hat{\mu}_{\pi,t+k}+(1-\rho)\gamma^{Res}\hat{\mu}_{y,t}+\rho r_{t-1}+\varepsilon_t \qquad (5.14)$$

In addition, we estimate the reaction function in Equation 5.14 augmenting with some foreign variables as federal fund rate and real effective exchange rate for the United Kingdom and real effective exchange rate for the United States. Adam et al. (2005), Clarida et al. (1998), Edwards (2006) and Chadha et al. (2004) also use exchange rate and foreign interest rate to investigate the foreign influence on domestic monetary policy in Taylor Rule.

5.4 Estimation Results

This section present and discusses the estimation results obtained from the variants of Taylor Rule. We estimate one quarter (k=1) and four quarter (k=4) forward looking Taylor Rule for the United States and the United Kingdom incorporating domestic, global and foreign variables as explained in section 3.3.

The United States

First, we consider the results for United States presented in Table 5.2. In Panel A of the Table, results from estimating one-quarter (k=1) forward looking Taylor Rule are presented while Panel B reports the results obtained from estimating one-year (k=4) forward looking Taylor Rule. The results show that the interest rate smoothing term is positive and significant in all specifications. The estimated coefficient on inflation and output gap for the baseline specification(Equation[1] for Panel A and [6] for Panel B in Table 5.2) with domestic variables in Panel A and B are positive and significant. The response of interest rate to inflation in Panel B fulfils the Taylor Principle as the coefficient on inflation is 1.71. The estimated coefficient on inflation for the baseline specification with global variables (estimated regressions [2] and [7] in the Table 5.2 for Panel A and B respectively, based on Equation 5.10) is positive and significant. The coefficient on global inflation in Panel B fulfils the Taylor principle. The weight on output gap is small and insignificant in both panels. The estimated coefficient on inflation for the baseline specification with residuals (estimated regressions [3] and [8] based on Equation 5.13, which represent the component of domestic inflation and output gap that is not related to global inflation and output gap) is large but insignificant whereas the coefficient on output gap is large and significant in both Panels.

The estimation of the specification where the global variables are incorporated with the residuals (estimated regressions [4] and [9] based on Equation 5.14), we find that the coefficient on the global inflation, the global output gap and the country specific output gap are positive and significant in Panel A and B. The coefficient on country specific inflation is positive in Panel A and negative in Panel B but insignificant in both cases. We estimate the reaction function specified in Equation 5.14 augmented with the changes in exchange rate and find significant coefficient on it in panel A and B. The probability of J-statistics reported in last column of the Table 5.2 shows that we can not reject the null hypothesis that model is valid and is not over identified .

Hence, the instruments used in each specification are appropriate.

A number of results presented in Table 5.2 and narrated above are interesting and noteworthy. First, the response of interest rate to inflation in estimated regressions [1], [2], [3] and [5] do not fulfil the Taylor principle in Panel A i.e. interest rates are not raised high enough to increase the real short term interest rate in one-quarter forward looking reaction function (the estimated co-efficient on inflation are 0.93. 0.85 and 0.78). This may suggest that the Federal Reserve do not react strongly to very short run (one quarter) changes in inflation. Only the specification [4] fulfils the Taylor principle where the model incorporates both the residuals and the global variables where the coefficient on global inflation is 1.04 while country specific inflation appears to small and insignificant. While, the coefficients on domestic and global inflation in almost all specification of the Taylor Rule in Panel B, where we estimate four quarter forward looking variants of the Taylor Rule, satisfy the Taylor principle (the estimated co-efficient on inflation are 1.71, 1.15 and 2.77 with the exception of 0.97). This implies that the monetary policy makers do not respond strongly to very short term variations in inflation rather they are more concerned to a year ahead inflation forecasts. This finding is consistent with Clarida et al. (2000) who state that policy makers are relatively less concerned with very short term variations in inflation. Instead, they are more concerned about medium to long term variations in inflation.[19]

Secondly, the estimated parameters obtained from Equation 5.9 and Equation 5.13 (i.e. estimated regression [1]and [3] in Panel A and [6] and [8] in Panel B) are significantly different. In Panel A, the estimated co-efficient on domestic inflation is positive and significant (0.93) whereas for the residual inflation it is 2.53 but insignificant. The co-efficient on residual output gap and domestic output gap is positive and significant (1.00 and 0.50 respectively). Panel B also shows significantly different estimates of parameters from the two equations (positive and significant for domestic inflation, i.e. 1.71 and positive and insignificant for residual inflation, i.e. 2.43). The domestic inflation and output gap in Equation 5.9 incorporate global influences and the residual inflation and output gap in Equation 5.13 are country specific i.e disentangled from

[19] Clarida et al. (1998) use one year horizon of inflation forecast while estimating monetary policy reaction function.

global shocks. Thus, by comparing the estimated parameters of both equation, we can infer that the global developments do significantly affect domestic monetary policy.

Moreover, the coefficients on the global inflation are positive and significant whereas the country specific inflation is insignificant in both panels. Moreover, when we incorporate the country specific inflation and output gap with the global inflation and output gap in the reaction function, the global inflation remains significant while the country specific inflation remains insignificant. This result implies that the Federal Reserve actually respond to global inflation only. This finding may not be surprising once we consider the high correlation between the global and domestic inflation rates. The coefficient of correlation between the United States domestic and global inflation is 0.77. This may be consistent with the argument made by Ciccarelli and Mojon (2010) that inflation has become a global phenomenon. The literature on globalization of inflation also provides evidence that inflation has become a global phenomenon. We report in Chapter 1 that almost 60 percent of the variance in the U.S. inflation can be attributed to the global and regional factors and only 38 percent of the variation in inflation is due to the country specific factors. Ciccarelli and Mojon (2010) find that almost 70 percent of the variance in inflation is attributable to a common global factor. Global output gap may affect domestic monetary policy in a globalized world through its impact on domestic inflation process as it is argued that domestic inflation has become sensitive to foreign output gap (see for example Borio and Filardo (2007)). The co-efficient on global output gap is positive and significant in some of the specifications of the Taylor Rules, however, the magnitude is lower than those on country specific output gap suggesting the importance of domestic output gap. .

Thirdly, we find that the Federal Reserve does respond to the changes in real effective exchange rate. The changes in exchange rate affect domestic monetary policy through real GDP by expenditure switching which in turn affects inflation. We find that one percent real depreciation of dollar induces 10 and 39 basis point increase in interest rate in Panel A and B respectively. For instance, depreciation of dollar will increase real GDP by expenditure switching which will put upward pressure on inflation and hence, the Federal Fund rate is increased by monetary policy authorities.

The United Kingdom

The estimates of monetary policy reaction functions for the United Kingdom are reported in Table 5.3. Panel A of the Table reports the estimation results for 1-quarter forward-looking reaction function with different specifications. Panel B presents the estimation results for four quarter forward-looking reaction function.

The results reported in panel A and B show that the policy makers at Bank of England concern very short term (a quarter) variations in inflation as well as medium (a year) and long term as opposed to the United States. In case of the United States, we find that inflation fulfils the Taylor principle only in a year forward-looking reaction function (while it is not followed in a quarter forward-looking reaction function, Panel A in Table 5.2 whereas for the United Kingdom it is satisfied in both cases; a quarter and year forward-looking reaction functions.[20] Interest rate smoothing term is positive and significant in all estimated specifications. The global inflation is significant in all cases irrespective of the specification used. The overall results regarding the monetary policy's response to global variables are not significantly different in one quarter forward looking and a year forward looking reaction functions (Panel A and Panel B). Hence, for further discussion of the results, we will concentrate on estimates of four quarter forward-looking reaction function (shown in Panel B).

The results reported in Table 5.3 show that the estimated coefficients on inflation and output gap for baseline model with domestic variable (estimated regression [7] in Table 5.3) are positive and significant. The magnitude of the coefficients on inflation and output gap is almost as suggested by the original Taylor Rule. The baseline reaction function estimated with global variables (regression [8] in Table 5.3) find that the coefficient on global inflation (3.16) is more than twice the coefficient on domestic inflation (1.28) and significant. While the magnitude on global output gap is small yet positive and significant. However, when we estimate the baseline reaction function with residuals (i.e. country specific inflation and output gap) it is found that

[20]this implies that forward looking behaviour of the United States differs from the United Kingdom. The United Kingdom is more pro-active to short run variations in inflation whereas the United States is unconcerned with short run changes in inflation.

the coefficient on country specific inflation is not significant while the coefficient on country specific output gap is well above unity and highly significant. The comparison of estimated regressions [1] and [3] in Panel A (based on Equation 5.9 that includes domestic inflation and output gap and Equation 5.13 that includes the country specific inflation and output gap, disentangled from global shocks) and [7] and [9] in Panel B verifies the effects of global developments on the U.K. monetary policy as the estimates of the parameters in two equations differ substantially in both panels.

To have an insight of the relative importance of global and the country specific inflation and output gap in monetary policy rule, we estimate a reaction function which incorporates both global and country specific variables. We find that the global inflation remains significant while the coefficient on country specific inflation becomes insignificant. The coefficient on global and country specific output gap is significant though the magnitude on country specific output gap is higher than the coefficient on global output gap.

The comparison of results in panel A and B of Table 5.3 shows that in very short run (one quarter) Bank of England considers and reacts to fluctuations in global as well as country specific inflation whereas in medium and long run (four quarter) it reacts to global inflation only.[21] This finding reflects the fact that inflation has become a global phenomenon as discussed by Ciccarelli and Mojon (2010). The estimates of weights on global and country specific output gap indicate that the country specific output gap is considered as more important than the global output gap while taking monetary policy decisions.

International variables such as exchange rate and foreign interest rate may affect domestic monetary policy through various channels. Changes in exchange rate affect domestic monetary policy through real GDP by expenditure switching which in turn affects inflation and hence, domestic monetary policy. Foreign interest rates may affect domestic interest rates through financial markets, investment flows and exchange rate channel (Giovanni and Shambaugh (2006)).

[21] The reaction function augmented with real effective exchange rate (regression [11]in Table 5.3) is the only exception where the coefficient on country specific inflation is 1.15.

The estimates of the reaction function that incorporates foreign variables such as real effective exchange rate and the Federal Reserve Fund rate in addition to global and the country specific inflation and output gap show that the Bank of England responds to exchange rate changes and foreign interest rate while setting the interest rates. One percent depreciation in Pound Sterling relative to a set of currencies of its trading partners induces a rise of 30 basis points in interest rate. The influence of foreign factors on the U.K. monetary policy may be due to its entry in ERM in 1990 and informal Deutsche Mark shadowing even before the entry in ERM. Adam et al. (2005) and Cobham (2002) suggest and provide the evidence that the Monetary Policy of the U.K was not focused only on Germany instead, it was also concerned about broader international developments. When the reaction function specified in Equation 5.14 is augmented with real exchange rate change, country specific inflation also becomes significant. The estimation of the reaction function augmented with the Federal Fund Rate (estimated regression[12] in Table 5.3) shows that the Bank of England policy rate is considerably affected by the U.S. interest rate (the estimated coefficient of Federal Fund rate (0.86) is significant at 1 percent level of significance). However, on the inclusion of the Federal Fund rate in the reaction function, global output gap and country specific inflation becomes insignificant. The interest rate smoothing is significant in all specifications and P-values of J-statistics shown in last column of the Table approve that choice of instruments is appropriate and the model is not over identified.

The estimates reported for baseline model with domestic variables are fairly consistent with the literature on Taylor Rules (Clarida et al. (1998) and Adam et al. (2005)). However, the strict comparisons cannot be made as the co-efficient on inflation, output gap and other variables augmented in Taylor Rules are sensitive to choice of sample period, measures of inflation and output gap and the specifications of monetary reaction function.

5.5 Robustness Checks

Our estimation results explained above clearly show that the monetary policy making of the United States and United Kingdom is considerably affected by international factors. The foreign variables such as global inflation, output gap, changes in real exchange rate and foreign interest rate appear significant in different specification of reaction function. However, it is interesting to note that the global inflation appears significant in all specification but the residual inflation (the country specific inflation) is mostly insignificant. This implies that the central banks do not react to the country specific inflation which seems surprising in the presence of formal Inflation Targeting framework in the United Kingdom and informal inflation targeting in the United States. We can do a robustness check by re- estimating the reaction function for United kingdom for a sub sample starting since 1992 (the year when U.K. formally adopted Inflation Targeting (1992-2010) and for the United States for a period starting since Greenspan became the chairman of the Federal Reserve (1987-2010). Thus we re-estimated the reaction functions for the sub samples with the same specification as earlier and the results are reported in Table 5.4 and 5.5 for the United States and United Kingdom respectively.

The results for the United States, presented in Table 5.4 endorse our earlier finding that the global inflation and changes in real exchange rate affect setting the monetary policy rate. The coefficient on global inflation is significant in every specification of reaction function. However, the estimation of the reaction function that incorporates both the global and residual variables shows that the coefficient on country specific inflation is significant though at 10 percent level. The coefficient on country specific inflation becomes significant at 5 percent level of significance when the reaction function is augmented with real exchange rate change. The global output gap does not seem to be considered by Federal Reserve while undertaking monetary policy.

The reaction function estimation results for the United Kingdom for the Inflation Targeting period is reported in Table 5.5. In line with the earlier findings for the full sample, it is found that global inflation is significant in all specifications and foreign interest rate and real exchange rate changes are also considered while setting the monetary policy rule. However, the estimation results in Panel B (four quarter forward-looking) indicate that the country specific (residual) output gap is not significant while global output gap is significant though the coefficient's magnitude is small.

In addition to sub-sample estimation, we estimated the Taylor Rule with the same specification as above using the inflation measure based on CPI inflation and expected inflation measured as explained in section 3.1. The Taylor Rule specifications with expected inflation are estimated using OLS. However, as we do not have data on measure of global expected inflation and output gap, we could not estimate the reaction function specifications including these variables. Thus we estimate the reaction function that use expected inflation augmenting with real exchange rate changes and foreign interest rate. The results are reported in Appendix C (Table C.1 for the United States and C.2 for United Kingdom for the inflation measure based on CPI inflation and in Table 3A for the inflation measure based on expected inflation). The results reported in Table C.1 and C.2 verifies our earlier finding that the international factors do affect the domestic monetary policy making of the United States and the United Kingdom. In Table C.3, the foreign interest rate and real effective exchange rate changes are considered while conducting monetary policy in the United Kingdom while changes in real effective exchange rate does not affect the monetary policy rule in the United States.

5.6 Conclusion

This Chapter investigates whether domestic monetary policy reaction functions of the United States and the United Kingdom are influenced by global variables. We estimate variants of the Taylor Rule which include the Taylor Rule with domestic variables (domestic inflation and output gap), with global variables(global inflation and out put gap), incorporating domestic and global variables in one reaction function and augmenting it with external variables such as real effective exchange rate and foreign interest rate. We computed global inflation and global output gap for the United States and the United Kingdom and find that the global measures of inflation and output gap are highly correlated with domestic inflation and output gap. To distinguish the domestic inflation and output gap from global effects we regress domestic inflation and output gap on the global inflation and output gap. The residuals obtained from this regression are used as the component of domestic inflation and output gap that is not related to the global variations. Then we estimated forward-looking policy reaction function for the United States and the United Kingdom with domestic and global inflation, output gaps. Moreover, we augmented policy reaction function with foreign variables such as real effective exchange rate changes and foreign interest rate.

We find strong empirical evidence that the policy makers at the Federal Reserve and the Bank of England consider the international factors while conducting monetary policy. For a sample period from 1985-2010, we find that they respond to the global inflation, global output gap and the country specific output gap while the country specific inflation appears as insignificant. The global inflation appears as significant irrespective of the specification used to estimate the Taylor Rule where the coefficient is well above unity. This result does not seem surprising once we consider the globalization of inflation. The literature on globalization of inflation (such as studies by Ciccarelli and Mojon (2010), Bagliano and Morana (2009) among many others) show that larger variance of domestic inflation rates is explained by international factors. Similar results were obtained when we estimated reaction function using the inflation measure based on CPI. However, contrary to the full sample estimation in sub sample estimation of the reaction function (1992-2010 for the United Kingdom and for 1987-2010 for the United States) we find that the country specific inflation as well as global inflation is taken into account while setting the monetary policy rate.

An other important result of the Chapter is the difference in forward looking behaviour of the Federal Reserve and of the Bank of England. We find that the Federal Reserve is more concerned about the medium and long term variation in inflation and does not follow the Taylor principle when responding very short term variation in inflation whereas the Bank of England strongly respond to short term variations in inflation as well. Moreover, we find evidence that the Federal Reserve respond to changes in real effective exchange rate and the U.K. monetary policy is also influenced by other external factors such as changes in real effective exchange rate and the federal fund rate. Our results are in line with Adam et al. (2005) and Clarida et al. (1998) (for the United Kingdom) and Chadha et al. (2004)(for the United States and the United Kingdom) who provide evidence of external influences on domestic monetary policy through exchange rate and foreign interest rates.

Table 5.1: Macroeconomic indicators: Summary statistics

Variable	**United States**		**United Kingdom**	
	Mean	Standard Deviation	Mean	Standard Deviation
Nominal Interest rate	4.59	0.24	6.82	0.36
Expected Inflation	2.64	0.08	4.12	0.15
Actual Inflation	2.64	0.87	3.52	1.89
Output Gap	0.0005	0.001	0.0002	0.001
Global inflation	2.26	0.12	2.57	0.13
Global output Gap	0.0004	0.001	0.0003	0.001

Notes: the table shows the mean and standard deviations of the variables for the United States and the United Kingdom.

Table 5.2: Taylor Rule estimations for the United States (1985-2010)

		c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	*P(j-statistics)*
Panel A												
Baseline Model with;												
[1]	Domestic Variables	2.21	0.93*	0.50***					0.86***		0.95	0.68
[2]	Global Variables	2.28**			0.85*	0.11			0.85***		0.95	0.53
[3]	Residuals	3.3					2.53	1.00**	0.95***		0.96	0.47
[4]	Global variables with residuals	1.97			1.04**	0.29**	0.57	0.64***	0.87***		0.96	0.42
Adding;												
[5]	Real Effective Exchange rate	2.57**			0.78*	0.36***	0.34	0.52***	0.84***	0.10*	0.95	0.75
Panel B												
Baseline Model with;												
[6]	Domestic Variables	0.06	1.71**	0.27*					0.85***		0.95	0.98
[7]	Global Variables	1.81			1.15**	0.16			0.77***		0.94	0.9
[8]	Residuals	3.37					2.43	0.97***	0.95***		0.95	0.42
[9]	Global variables with residuals	2.46			0.97**	0.25**	-0.05	0.44***	0.83***		0.95	0.33
Adding;												
[10]	Real Effective Exchange rate	-0.61			2.77***	0.14	0.77	0.62***	0.88***	0.39***	0.95	0.56

Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1985-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.S. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.S. output gap on the global output gap. The residuals are obtained to measure the U.S. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ denotes the coefficient on real effective exchange rate. $\bar{R}^2$ is adjusted R^2 and *P(j-statistics)* is p value of J-statistics, a test for validity of the instruments used. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 level respectively.

Table 5.3: Taylor Rule estimations for the United Kingdom (1985-2010)

	c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	*P(j-statistics)*
Panel A											
Baseline Model with;											
[1] Domestic Variables	0.79	1.43***	0.40***					0.88***		0.96	0.83
[2] Global Variables	1.91			1.47**	0.07			0.88***		0.94	0.77
[3] Residuals	2.56					1.22	1.44***	0.96***		0.95	0.94
[4] Global variables with residuals	0.38			2.03***	0.29***	1.28***	0.32***	0.87***		0.96	0.92
Adding;											
[5] Real Effective Exchange rate	-0.01			2.23***	0.12	1.08**	0.28**	0.87***	0.23***	0.96	0.98
[6] Federal Fund Rate	-1.05			1.22***	0.03	0.81***	-0.09	0.76***	0.87***	0.96	0.93
Panel B											
Baseline Model with;											
[7] Domestic Variables	1.05	1.28**	0.48**					0.92***		0.95	0.57
[8] Global Variables	-1.91**			3.16***	0.21***			0.65***		0.88	0.82
[9] Residuals	3.35					-3.9	2.62***	0.97***		0.95	0.8
[10] Global variables with residuals	2.17			1.53**	0.41**	0.82	0.69***	0.91***		0.95	0.78
Adding;											
[11] Real Effective Exchange rate	0.54			2.09***	0.14*	1.15**	0.36***	0.87***	0.30***	0.95	0.92
[12] Federal Fund Rate	-0.56			1.13***	-0.02	0.32	0.37***	0.86***	0.86***	0.95	0.87

Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1985-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.K. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.K. output gap on the global output gap. The residuals are obtained to measure the U.K. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ is coefficient on the variables added in Taylor Rule i.e. Real Effective Exchange Rate and the Federal Fund Rate. $\bar{R}^2$ is adjusted R^2 and *P(j-statistics)* is p value of J-statistics, a test for validity of the instruments used. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate and federal fund rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Table 5.4: Taylor Rule estimations for the United States (Greenspan-Bernanke era)

		c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	*P(j-statistics)*
Panel A												
Baseline Model with;												
[1]	Domestic Variables	1.89*	0.84**	0.48***					0.87***		0.96	0.84
[2]	Global Variables	0.32			3.17**	0.59			0.94***		0.93	0.76
[3]	Residuals	3.93*					0.98	1.12***	0.93***		0.96	0.47
[4]	Global variables with residuals	-1.41			3.66**	0.21	2.82**	1.46***	0.96***		0.95	0.91
Adding;												
[5]	Real Effective Exchange rate	0.98			2.43***	0.27	1.61**	0.99***	0.94***	0.21*	0.95	0.97
Panel B												
Baseline Model with;												
[6]	Domestic Variables	0.62	1.35**	0.47***					0.89***		0.96	0.47
[7]	Global Variables	1.38			2.13**	0.71**			0.90***		0.93	0.8
[8]	Residuals	4.67**					0.58	1.49***	0.94***		0.95	0.58
[9]	Global variables with residuals residual	0.14			1.57**	0.28	1.65*	0.78***	0.90***		0.96	0.86
Adding;												
[10]	Real Effective Exchange rate	-1.99			2.75***	0.19	1.53**	0.81***	0.89***	0.24**	0.96	0.86

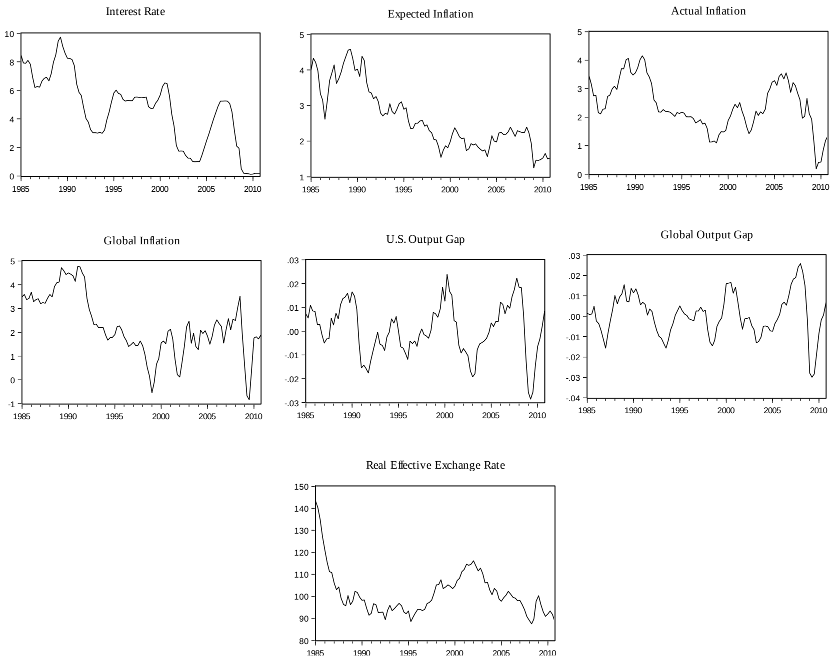
Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1987-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.S. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.S. output gap on the global output gap. The residuals are obtained to measure the U.S. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ denotes the coefficient on real effective exchange rate. $\bar{R}^2$ is adjusted R^2 and *P(j-statistics)* is p value of J-statistics, a test for validity of the instruments used. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Table 5.5: Taylor Rule estimations for the United Kingdom (Inflation Targeting regime 1992-2010)

	c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	*P(j-statistics)*
Panel A											
Baseline Model with;											
[1] Domestic Variables	1.08	1.06**	0.66***					0.91***		0.90	0.65
[2] Global Variables	2.42*			1.76***	0.62***			0.84***		0.83	0.6
[3] Residuals	2.88					2.49**	1.31***	0.94***		0.87	0.2
[4] Global variables with residuals	1.57			1.22***	0.15*	0.54*	0.55***	0.85***		0.89	0.62
Adding;											
[5] Federal Fund Rate	-0.90			1.10***	-0.09**	0.37**	0.31***	0.74***	0.82***	0.92	0.62
[6] Real effective Exchange rate	-2.81			3.16***	0.31***	0.87*	0.69***	0.91***	0.57***	0.92	0.82
Panel B											
Baseline Model with;											
[7] Domestic Variables	-1.3	2.23***	0.28*					0.90***		0.85	0.83
[8] Global Variables	-1.85			3.16**	0.20*			0.87***		0.82	0.65
[9] Residuals	4.43***					-0.43	0.42***	0.82***		0.84	0.55
[10] Global variables with residuals	2.01			0.82*	0.19***	0.94**	0.22	0.82***		0.82	0.69
Adding;											
[11] Federal Fund Rate	1.48			0.64*	0.12**	1.48***	0.17	0.78***	0.40***	0.82	0.60
[12] Real Effective Exchange rate	0.40			1.76**	0.14*	1.62***	0.06	0.86***	0.41***	0.87	0.96

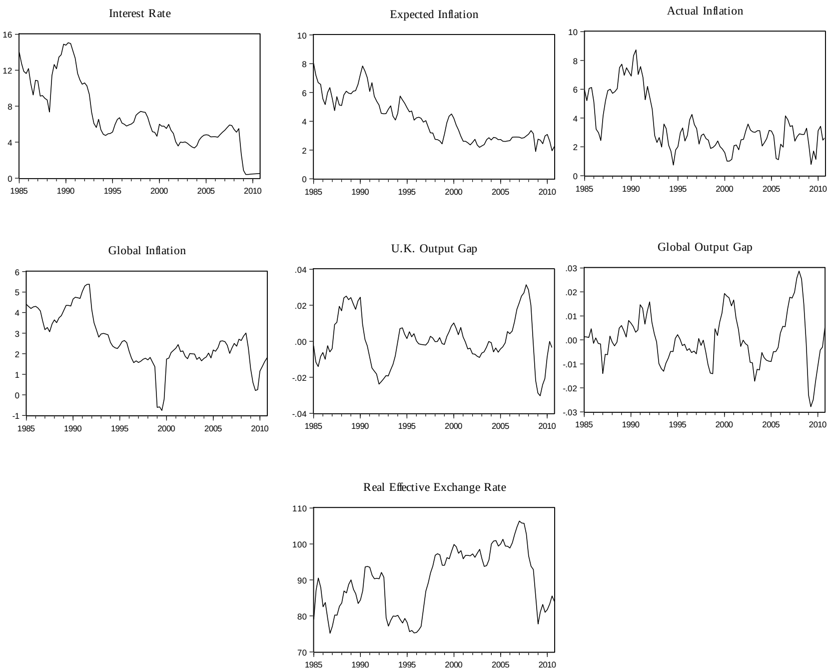
Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1992-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.K. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.K. output gap on the global output gap. The residuals are obtained to measure the U.K. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ is the coefficient on the variables added in Taylor Rule i.e. Real Effective Exchange Rate and the Federal Fund Rate. $\bar{R}^2$ is adjusted R^2 and *P(j-statistics)* is p value of J-statistics, a test for validity of the instruments used. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate and federal fund rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Figure 5.1: The United States: Interest rate, domestic and global Inflation, domestic and global output gap and real effective exchange rate dynamics



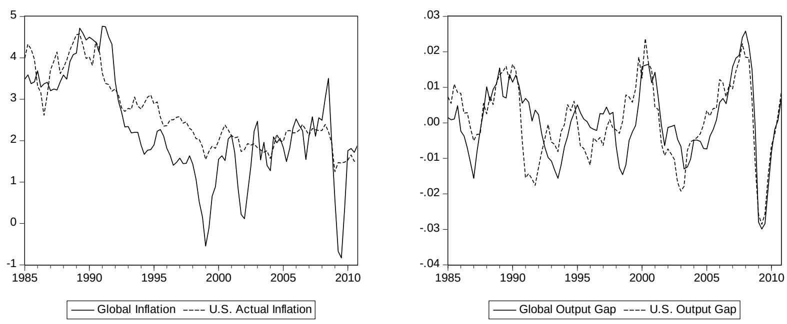
Note: The figure shows dynamics of interest rate, expected and actual inflation, global inflation, global output gap and real effect exchange rate for the United States over the period 1985-2010. Interest rate is the Federal Fund Rate, expected inflation is one year ahead inflation forecasts from the survey of professional forecasters obtained from the Federal Reserve Bank of Philadelphia website, domestic inflation is percentage change in GDP deflator, domestic output gap is measured as log of seasonally adjusted real GDP detrended using HP filter. Global inflation is computed as the weighted average of the U.S. twenty largest trading partner's inflation rates. Global output gap is measured as the weighted average of output gaps of twenty largest trading partner countries. real effective exchange rate is trade weighted index (REER, 2005=100) obtained from IMF international Financial Statistics ESDS.

Figure 5.2: The United Kingdom: Interest rate, domestic and global inflation, domestic and global output gap and real effective exchange rate dynamics



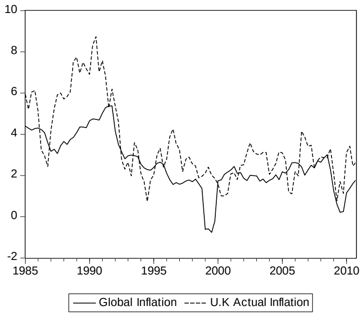
Note: The figure shows dynamics of interest rate, expected and actual inflation, global inflation, global output gap and real effective exchange rate for the United Kingdom over the period 1985-2010. Interest rate is the overnight interbank lending rate, expected inflation is four year implied inflation forward rate expectation obtained from the Bank of England website, domestic inflation is percentage change in GDP deflator, domestic output gap is measured as log of seasonally adjusted real GDP detrended using HP filter. Global inflation is computed as the weighted average of the U.K. twenty largest trading partner's inflation rates. Global output gap is measured as the weighted average of output gaps of twenty largest trading partner countries. real effective exchange rate is trade weighted index (REER, 2005=100) obtained from IMF international Financial Statistics ESDS.

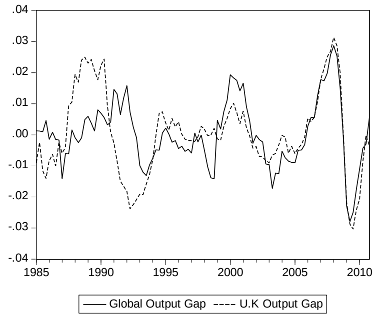
Figure 5.3: Global and domestic inflation and output gap for the United States



Note: The figure compares the estimates of global and domestic inflation and output gap for the United States.

Figure 5.4: Global and domestic inflation and output gap for the United Kingdom





Note: The figure compares the estimates of global and domestic inflation and output gap for the United Kingdom.

Appendices

Appendix C

Appendix to Chapter 5: Monetary Policy Reaction Function for the United States and the United Kingdom: A Global Perspective

Table C.1: Taylor Rule estimations for the United States (1985-2010) (Inflation measure is based on CPI)

	c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	P(*j-statistics*)
Panel A											
Baseline Model with;											
Domestic Variables	1.46	1.07**	0.43***					0.86***		0.95	0.42
Global Variables	3.99**			0.09	0.19			0.87***		0.94	0.58
Residuals	3.1					2.18*	0.80**	0.92***		0.96	0.57
Global variables with residuals	1.41			1.22*	0.29	1.85**	0.40**	0.87***		0.96	0.42
Adding;											
Real Effective Exchange rate	-2.94			3.55***	0.39***	3.08***	0.41	0.91***	-0.03	0.94	0.91
Panel B											
Baseline Model with;											
Domestic Variables	0.73	1.25**	0.35***					0.86***		0.96	0.44
Global Variables	0.28			1.40**	0.33			0.69***		0.92	0.9
Residuals	2.45					1.01	1.04***	0.92***		0.95	0.31
Global variables with residuals	-0.06			2.06***	0.32**	1.19*	0.26**	0.80***		0.95	0.54
Adding;											
Real Effective Exchange rate	-0.85			2.88***	0.35***	1.02*	0.38***	0.86***	0.17***	0.95	0.86

Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1985-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.S. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.S. output gap on the global output gap. The residuals are obtained to measure the U.S. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ denotes the coefficient on real effective exchange rate. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Table C.2: Taylor Rule estimations for the United Kingdom (1989-2010)(Inflation measure is based on CPI)

	c	β	γ	β^G	γ^G	β^{Res}	γ^{Res}	ρ	ξ	$\bar{R}^2$	*P(j-statistics)*
Panel A											
Baseline Model with;											
Domestic Variables	2.47**	1.03*	0.48***					0.89***		0.96	0.73
Global Variables	1.82			1.43**	0.21***			0.78***		0.95	0.47
Residuals	4.71**					1.21	1.01**	0.94***		0.96	0.5
Global variables with residuals	-0.26			2.23**	0.09	1.02***	0.50***	0.88***		0.96	0.45
Adding;											
Federal Fund Rate	-1.19			0.90*	0.01	0.39*	-0.06	0.82***	1.12***	0.97	0.85
Real Effective Exchange rate	0.27			2.47**	0.05	1.17***	0.01	0.89***	0.40***	0.96	0.81
Panel B											
Baseline Model with;											
Domestic Variables	2.75***	1.06**	0.28***					0.88***		0.95	0.65
Global Variables	2.06*			1.52***	0.03			0.86***		0.93	0.63
Residuals	5.65**					0.64	0.72***	0.93***		0.96	0.46
Global variables with residuals	0.75			1.90*	0.08	0.41	0.49***	0.90***		0.96	0.82
Adding;											
Federal Fund Rate	0.04			0.95**	-0.02	0.62	0.09*	0.86***	0.86***	0.96	0.94
Real Effective Exchange rate	2.87**			1.08*	0.17*	1.03**	0.24	0.88***	0.30***	0.97	0.71

Notes: Panel A reports the estimates of one quarter forward looking Taylor Rules with different specification. Panel B gives the estimates of one year (four quarter) forward-looking Taylor Rules. The sample period is from 1989-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on domestic inflation rate, γ is coefficient on domestic output gap. β^G and γ^G are coefficients on global inflation and output gap respectively. β^{Res} is the coefficient on the residual inflation obtained by regressing the U.K. inflation on the global inflation and γ^{Res} is the coefficient on the residual output gap obtained by regressing the U.K. output gap on the global output gap. The residuals are obtained to measure the U.K. inflation and output gap that is not correlated to global inflation and output gap (as explained in the text). The ρ is smoothing parameter and ξ is coefficient on the variables added in Taylor Rule i.e. Real Effective Exchange Rate and Federal Fund Rate. The Taylor Rule is estimated using GMM. The instruments list contains the lagged values of interest rate, inflation, output gap and lagged values of residuals and exchange rate and federal fund rate when appropriate. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Table C.3: Taylor Rule estimates for the United Kingdom and the United States (1985-2010) (Inflation Expectations used as inflation measure)

	c	β	γ	ρ	ξ	$\bar{R}^2$
Panel A: United Kingdom						
Baseline Model	-1.64	1.85**	0.45***	0.85***		0.96
Adding;						
Federal Reserve interest rate	-1.55	0.98*	0.19**	0.80***	0.83**	0.96
Real Effective Exchange rate	-1.48	1.84**	0.36***	0.84***	0.17**	0.96
Panel B: United States						
Baseline Model	-1.72	2.16**	0.33*	0.87***		0.96
Adding;						
Real Effective Exchange rate	-1.79	2.24**	0.33**	0.86***	0.07	0.97

Notes:Panel A reports the estimates of forward looking Taylor Rules with different specification for United Kingdom. Panel B gives the estimates of forward-looking Taylor Rules for the United States. The sample period is 985-2010. The first row of Table contains parameters in the model where c is the constant, β is coefficient on inflation rate, γ is coefficient on domestic output gap, ρ is smoothing parameter and ξ is coefficient on the variables added in Taylor Rule i.e. Real Effective Exchange Rate change and Federal Fund Rate. Ordinary Least Square (OLS) is used as estimation method. The asterisks ***, **, * indicate significance at the 1, 5, 10 percent level respectively.

Chapter 6

Conclusion

In this thesis, we examine the impact of globalization on aggregate and sectoral level inflation and its implications for the conduct of monetary policy. Globalisation refers to increased integration and interdependence of national economies as reflected in greater and freer flow of goods, services, capital, and labour across national borders. Improvements in information and communication technology have been important drivers of globalization. Hence, a globalized world where goods and services can be easily sourced from cheap suppliers, access to foreign financial markets is readily available and capital flows across national borders may have important implications for the monetary policy. In this context, our research addressed a number of issues in the recent debate on globalization and monetary policy. We investigate the impact of global factors on inflation from an aggregate and sectoral perspective by measuring the co-movements in inflation rates across countries. Moreover, we examine whether high co-movements in inflation rates across countries have any relationship with measures of globalization. Finally, we consider the implications of globalization for monetary policy in the United States and the United Kingdom by estimating monetary policy reaction function in an international setting.

Globalisation affects the structure and working of financial and economic environment in which monetary policy operates so the conduct of monetary policy is also influenced. The changes in economic environment due to global forces may alter the relative importance of the channels through which monetary policy works. The theory suggests that the key elements of the monetary policy framework such as inflation process and transmission mechanism may be affected by the global integration of financial and goods markets through various channels. Though in the long run inflation may always and every where be a monetary phenomenon as suggested by Milton Friedman yet short and medium run dynamics of inflation are affected by globalisation(Mishkin (2009)). Moreover, globalization may have permanent effects on prices.

The importance of the implications of globalisation for monetary policy is emphasized by Central Bankers and academic researchers. It has been generally accepted that monetary policy authorities can no longer ignore the international developments in a globalized environment. Consequently, monetary policy making has become challenging. Theoretically, globalisation may affect inflation and monetary policy through several channels. First, Globalization may directly affect the monetary policy through changing the environment in financial markets. In integrated financial markets, transmission mechanism of monetary policy may get affected by changing the relative importance of transmission channels (Meier (2012)). Moreover, the responsiveness of long term interest rate to short term rates may decease due to influences of international market conditions on long term interest rate. Secondly, financial globalisation i.e. greater international capital mobility may have disciplinary affect through inducing Central Banks to conduct sound monetary policy (Spiegel (2009)).

Globalization may affect domestic inflation through trade. Trade integration may have a direct effect on inflation through import price channel and an indirect effect through increased competitive pressures. Cheap imports from China and other developing countries put downward pressure on prices when these imports are used as input in production process. The indirect effect through increased competition put downward pressure on prices by decreasing the monopoly power of firms, increasing price elasticity of demand and forcing producers to lower margins. However, the effects may not be in one direction. The downward pressure on prices due to lower imports may enhance the purchasing power of consumers which they will use to buy other products putting upward pressure on prices of those products. secondly, increased international trade is associated with high productivity growth in emerging economies such as China and India. The high demand for raw materials from these countries put upward pressure on industrial commodity prices. These offsetting effects may be one of the reasons of sceptical and mixed empirical evidence on effects of globalization on domestic inflation.

Another statistical indicator of effects of globalization on inflation is measure of co-movements in inflation rates across countries. Inflation rates are observed to co-move substantially in many countries during last few decades. Ciccarelli and Mojon (2010) and Bagliano and Morana (2009) find that almost 70 percent of the variance in national inflation rates is explained by a common global factor. Neely and Rapach (2011) also capture global and regional component in inflation series of a large number of advanced and developing economies. They also noted that a significant amount of variations in the domestic inflation is shared by global factors. Monacelli and Sala (2009) and Mumtaz and Surico (2012) measure the co-movements in disaggregated inflation. However, the studies in existing literature on globalization of inflation assume that volatility of inflation remains constant (Mumtaz and Surico (2012) is an exception). This assumption is not realistic as volatility of inflation has considerably decreased overtime. secondly, the importance of regional economic linkages is ignored in the literature (Neely and Rapach (2011) estimate regional factors but they do not take into account stochastic volatility).

We contribute to the literature on globalization of inflation in number of direction. First, we take into account the time variation in the volatility of inflation. Secondly, we consider the strong regional economic linkages enhanced by proliferation of trade agreements and common currency areas. Hence, we estimate global and regional factors. Thirdly, we find empirical relationship between the estimated common factors and economic globalization. To complement and deepen our understanding of inflation globalization, we measure the co-movements in sectoral level inflation. As globalization does not affect all the sectors of an economy with same extent, the degree of trade openness and market competitiveness differ considerably across sectors of an economy. Thus, the sectors that are more exposed to foreign trade must experience higher co-movements in inflation rates across countries if trade openness is responsible for highly synchronized inflation rates.

In Chapter 3 of our thesis, we measure the co-movements in aggregate inflation rates of 22 OECD countries. We estimate the Dynamic Factor Model with Stochastic Volatility to decompose inflation into a global factor, regional factors and country specific factors. The regions are determined both exogenously and endogenously. The regions are determined endogenously using K-means clustering where data is allowed to determine the regional composition of countries in our sample. However, endogenously determined regional composition does not allow us to examine the effects of the creation of European Monetary System (EMS) and the Euro on regional factor the member countries of the EMS and Euro were not grouped together. Hence, we used three different compositions of exogenously determined regions to take into account the effects of the European Monetary System (EMS) and the Euro on regional factors. Finally, we estimate the empirical relationship between the estimated common factors (global and regional) and economic globalization (a measure based on KOF index of globalization).

We find that significant amount of variance in inflation is explained by national factor. However, the role of global factor in explaining the variance of inflation has increased over time while national factor has been loosing its contribution. The variance of inflation attributable to the regional factor has increased for the countries that have established strong intra regional linkages. For the European countries, global and regional factors together become dominant in explaining the variance of inflation while the national factor becomes less important (less than 50 percent) since 1999. We find a considerable heterogeneity in results across countries. For the U.S. more than 50 percent of the variance in inflation is explained by the global factor while for Korea, Greece and Australia more than 90 percent of the variance in inflation is explained by the country specific factors. Our results are in line with the results produced by Neely and Rapach (2011) and partially agree with Mumtaz and Surico (2012) to the extent that they also find national factor as an important factor in explaining the variance of inflation. The volatility of inflation has markedly declined in most countries which is mainly attributable to reduced volatility of idiosyncratic disturbance term.

We find that the formation of EMS and the steps followed to integrate the Europe such as the formation of European Monetary Union (EMU) and adopting the Euro as common currency, contributed in synchronizing the inflation rates in the region. The contribution of regional factor in explaining the variance of inflation in the region that consists of the EMS founding members is higher in Post-EMS period. We find that importance of the country specific factor decreases from more than 70 percent to less than 40 percent after 1999 in the European countries. This reflects role of the Euro in he synchronization of inflation in the European countries. Moreover, we find a positive and significant relationship between the high co-movements of inflation rates across countries and economic globalization. This relationship has become stronger since 1999. The more a country is globalized economically, the higher variance of its inflation rate is attributable to international factors.

In Chapter 4, we examine the globalization of inflation from a sectoral perspective. Monacelli and Sala (2009) also estimated the Dynamic Factor Model to capture the global factor from a highly disaggregated data. However, we argue that estimating a common global factor from disaggregated data may underestimate the co-movements as the degree of global integration differs across sectors. Hence, we decompose the sectoral inflation of 15 OECD countries (each country includes 15 sectors) into a global factor, sector specific factors and idiosyncratic component by employing the Dynamic Factor Model. The global common factor captures the effect of a global shock on all sectors of all countries and the sector specific factors capture the effects of shocks that affect particular sectors in all countries. This allows us to examine the co-movements in tradable and non-tradable sectors across countries with expectation that inflation in tradable sectors must experience higher co-movements than non-tradable sector. Finally, to test whether high co-movements in sectoral inflation across countries are associated with high degree of trade openness, we examine the relationship between the sector specific factor and sectoral trade openness. We use import penetration and ratio of imports and exports to sectoral output as measures of trade openness.

We find that on average the loadings on the global factor and variance of disaggregate inflation explained by the global factor is not different for tradable and non tradable sectors. However, the importance of sector specific factors in explaining the volatility of disaggregate inflation is substantially greater for tradable sectors than non tradable sectors. This result justify our approach to estimate the sector specific factor along with the global factor and implies that strikingly high co-movements of sectoral inflation rates are function of increased trade integration. Further, we find positive relationship between the global factor,sector specific factors and trade openness measured as import penetration.

The results of chapter 3 and 4 show that inflation has become global at aggregate and sectoral level. The globalization of inflation may have important implication for monetary policy as it is the key macroeconomic variable from monetary policy perspective. In chapter 5, we consider this and estimate a monetary policy reaction function for the United States and the United Kingdom. The Taylor type monetary policy rule in international context are estimated by augmenting it with foreign variables such as foreign interest rates, real exchange rates, terms of trade gap be several authors (For example, Adam et al. (2005), Clarida et al. (1998) and Edwards (2006)). We contribute to the literature on Taylor type rules in international setting by estimating the Taylor Rule with global inflation and global output gap and foreign variables such as real effective exchange rate and foreign interest rate.

We find strong empirical evidence that the policy makers at the Federal Reserve and the Bank of England consider the international factors while conducting monetary policy. For a sample period from 1985-2010, we find that the Bank of England strongly responds to global inflation along with domestic variables. The Federal Reserve responds to global inflation, global output gap and domestic output gap whereas the country specific inflation remains insignificant. It was found that the Federal Reserve is more concerned about the medium and long term variation in inflation and does not follow the Taylor principle when responding to very short term variation in inflation whereas the Bank of England strongly responds to short term variations in inflation as well. Moreover, we find that the Central Banks also respond to changes in real effective exchange rate. The Bank of England responds to the Federal Fund rate. Similar results were obtained when we estimate the reaction function using the inflation measure based on CPI. However, contrary to full sample result, in sub sample analysis for the United States (Greenspan-Bernanke era) we find that the Federal Reserve responds to country specific inflation and output gap along with global inflation whereas global output gap become insignificant.

The strong response of the Central Banks to global inflation and less significant response to global output gap may reflect that inflation rates are more globalized internationally whereas output is less synchronized across countries (Bagliano and Morana (2009) and Wang and Wen (2007)). The domestic inflation rates are highly correlated to global inflation as documented by Ciccarelli and Mojon (2010) and Bagliano and Morana (2009) that almost 70 percent of the variations in domestic inflation are shared by a global factor. Thus, even if the Central Banks target domestic inflation rates, global inflation is significant as considerable movements in domestic inflation are driven by global factors. It suggests that monetary policy authorities should consider the international factors and the extent to which these factors influence domestic variables.

To summarise, this thesis investigated the importance of global factors for monetary policy and inflation which is a key goal variable from monetary policy perspective. We find that global factors are important for inflation rates in OECD countries and their importance has increased over time. Regional effects are important for inflation rates of the countries which have strong regional linkages due to regional trade agreements and common currency areas. It is found that importance of the global factor in explaining the variance of aggregate inflation has increased over time. The national factors are dominated by global and regional factors in the European countries since 1999. We find positive and significant relationship between the estimated common factor and economic globalization. The investigation of sectoral inflation shows that the sectors that are more integrated internationally due to trade, experience higher co-movements than the sectors that are less exposed to international trade. The monetary policy reaction functions for the United States and the United Kingdom show that global inflation and global output gap are significant along with domestic variables. This implies that global variables should not be ignored and should be given appropriate weight while forecasting domestic inflation and making monetary policy rules.

Our results have important implications for monetary policy. The highly synchronized inflation rates at aggregate and sectoral level implies that inflation is strongly driven by global factors. The key variable that monetary policy aims to control is inflation. Even if monetary policy authorities target domestic inflation, a larger variance of domestic inflation is explained by global factor. Hence, the globalization of inflation must not be ignored by the Central Bankers. They can no longer ignore the international developments while making monetary policy.

Our research can be further extended in number of ways. First the global factors estimated from a number of macroeconomic variables by employing the Dynamic Factor Model could be used in structural vector autoregression (VAR) model, a Factor-augmented VAR (FAVAR) methodology proposed by Bernanke (2005) to measure the effects of monetary policy innovations on domestic and global variables. Secondly, the global inflation and output gap estimated by the Dynamic Factor Model could be incorporated in GMM to estimate the monetary policy reaction function in global perspective. Finally, a potential extension is to incorporate the financial conditions in monetary policy reaction function to examine the effects of financial globalization on monetary policy. The Taylor Rule could be augmented with some measures of financial conditions.

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