Essays in International Macroeconomics: Global Liquidity, Cross-border Spillovers, and Emerging Economies

Ratih Puspitasari

Doctor of Philosophy

University of York

Economics

December 2017

Abstract

This thesis contributes to our understanding of the implications of global liquidity and cross-border spillovers to emerging economies and its policy implications. First, it analyses the empirical regularity on the impact of the United States (US) Quantitative Easing (QE) -as a compelling case of the international dimension of monetary policy- on the global stability and policymaking. It then utilises a more theoretical framework to examine the empirical findings. We find that the effectiveness of QE varies across episodes, with QE1 having a substantially positive influence on the global economy, but the impact of QE2 and QE3 were moderate. There is evidence that US QE periods were responded by monetary easing in the rest of the world that materialised through the long and short rates. This monetary easing response slows down capital inflows, an expected effect if inflows are destabilising. However, the impact can be detrimental if the inflows are used to fund investment in the domestic economy. Then we focus on the reverse policy action, the Fed lift-off, to examine how the monetary authorities in other economies should respond by considering not just monetary policy but also macroprudential policy. We find that, without macroprudential policy, the less financially integrated economies are affected less by the lift-off, but those applying a fixed exchange rate regime are affected more. Nevertheless, macroprudential policy is significantly effective in reducing fluctuations in both types of economies. We then empirically study the determinants of global banking liquidity and establish an international banking connectedness map. We find that an increase of global liquidity is significantly caused by a rise in the US policy rate and global credit-to-GDP gaps; whereas an appreciation of the US Dollar and an increase in the TED spread have significant opposite effects.

Contents

List of Tables

List of Figures

Dedication

This thesis is dedicated to my husband, Andy Zulkarman Nasution, the biggest supporter of my PhD journey, and my lovely children, Diandra, Pupun, and Aan Nasution. I give my deepest expression of love and appreciation for encouragement and sacrifices they made during my PhD life. This work is also dedicated to my parents, Wiratnoko Wignyohamijoyo, Tuminah Wiratnoko, Mustafa Jhon Nasution, and Esmi Lubis for their unconditional love, constant support, and prayers.

Acknowledgements

Praise only be to Allah, the Most Gracious, the Most Compassionate, whose love is forever unconditional, near, and warm.

I extend my deepest gratitude to my supervisors, Professor Gulcin Ozkan and Dr. Michael Thornton, for their enormous guidance, encouragement, help, and assistance during the entire period of my study. Their lectures, which I attended during my earlier times of study, have been inspiring to me. I will always be indebted by their kindness, patience, and understanding. I would also like to extend my gratitude to Professor Yongcheol Shin, my Thesis Advisory Panel member for his teachings, discussion, and guidance. I also very much appreciate the effort of my examiners, Professor Kevin Lee and Dr. João Madeira, to read my work and give feedback.

I would also like to thank all the research staff in the Department of Economics and Related Studies (DERS), University of York, for the opportunity for me to learn so much thought-provoking new knowledge through their lectures, presentations, and discussions. My gratitude is also extended to all administrative staff in the DERS, their support in research facilities has always been exceptional.

I thank Bank Indonesia for giving me the opportunity to pursue my dream in researching what I love, learning new skills, and for supporting me morally and financially. I especially wish to thank Uni Rita Morena for always believing in me from the first time I said I wanted to pursue a PhD, Ibu Aida Budiman, Uni Sari Nadia, and Bapak Endang Kurnia Saputra for supporting me, Dian Pramasti Damayanti for our friendship and your continuous support. My thanks are also extended to all staff in the Human Resource Department, the Representative Office in London, and all BI friends for their continuous encouragement.

I am deeply grateful to all my fellow PhD friends, especially Suska, Aida Garcia-Lazaro, Lisha Li, Zhechun He, Blanca Guízar Morán, Telviani Savitri, and Indonesian students in York for their friendship, love, support, and kindness during my PhD life. My daily PhD life has been so much more enjoyable with them around.

My warmest thanks goes to my husband, Andy Zulkarman Nasution, for his love, patience, and understanding especially through difficult times, also to my children, Diandra, Puandra, and Aan Nasution, for always being amazing and best-in-the-world children. Mum is always proud of you. My thanks also goes to my parents, Wiratnoko Wignyohamijoyo, Tuminah Wiratnoko, Mustafa Jhon Nasution, and Esmi Lubis for their unconditional love, constant supports, and prayers. I also thank my sister Niken Wahyuningsih and family, and my brother Joko Yuliantoro and family for their encouragement.

Author's declaration

I declare that this thesis is a presentation of original work. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References. Chapter 4 is joint work with my supervisor, Professor Gulcin Ozkan, and Dr. Filiz Unsal from the International Monetary Fund.

Chapter 2 was presented at a Research Students Workshop in Department of Economics, University of York, in January 2016; the 5th White Rose Economics PhD Conference, University of York, in March 2016; the International EuroConference on Emerging Market Economies, University of Porto, in June 2016; the 48th Money, Macro and Finance Research Group Annual Conference, University of Bath, in September 2016; and the 4th Workshop in International Economics and Finance, Universitè de Bordeaux, in December 2016.

Chapter 3 was presented at the 6th White Rose Economics PhD Conference, University of Sheffield, in April 2017.

Chapter 5 was presented at the International Conference on the Finance and Economic Growth in the Aftermath of the Crisis, University of Milan; and the 5th Macro Banking and Finance Workshop, Universitá Cattolica del Sacro Cuore Milan, both in September 2017.

Chapter 1

Introduction

The world economy has witnessed a process of ever-deepening international financial integration since the end of the 20th century. The integration has allowed the great majority of countries to become open economies actively involved in the international trading of financial assets. Openness to international markets has brought many opportunities for emerging economies in advancing their national developments by broadening the scope of financing resources. The establishment of international financial institutions in host economies also introduces the local financial institutions to healthy competition and allows them to learn from the international best practices in financial services, thus improving the local financial markets' efficiencies. As a healthy financial market is pivotal for economic development, the increasing financial markets efficiency helps in ensuring stable economic growth in the long run.

Despite the opportunities that financial integration has to offer, the integration also comes with significant challenges for small open emerging economies. In particular, the openness to international financial markets exposes these economies to external financial shocks. A high financial integration facilitates monetary condition spillovers as revealed by an increasing tendency of asset price co-movement across different economies. This global asset price co-movement tends to evolve in line with global liquidity dynamics, but opposite to global financial risk measures. The 2007-08 global financial crisis has demonstrated the importance of global financial spillovers, where a credit tightness in some advanced economies led to massive capital outflows from the other economies and thus generated credit tightness worldwide. The policy stance taken by the United States' (US) authority to resolve the problem at the time shows that not only does integration facilitate financial spillovers during a crisis, it may also transmit *policy* spillovers beyond its national borders.

Against this development, policymakers in the emerging economies face increasingly critical challenges of maintaining the benefits of financial integration for domestic development, but at the same time minimising its negative consequences. They also need to comprehend the role of the US policy stance -whose currency is the most significant reserve currency- and the role of the international financial institutions in determining the global liquidity dynamics. As international financial shocks affect emerging economies differently, it is also crucial to understand how some inherent characteristics of the emerging economies differentiate the effect of external financial and policy shocks to these economies. More importantly, what set of policy strategies do the small open emerging economies need to possess to be prepared for negative consequences of the external shocks? Motivated by these questions, this thesis consists of four main chapters aiming to investigate the implications of cross-border monetary spillovers on the development of open emerging economies, also to shed some light on the determinants and ramifications of global liquidity, and to analyse the appropriate policy strategies for the emerging economies.

The United States (US) Quantitative Easing (QE) is a compelling case of international dimensions of monetary policy. Hence, the second chapter is dedicated to studying the implications of the QE on the monetary and financial conditions in the other advanced and emerging economies. In addition, we investigate whether the QE alters monetary policymaking in non-US economies. The QE was introduced when the US policy rate was bounded by the zero lower bound following an aggressive monetary policy easing with no significant improvements in the credit condition. The Federal Reserve utilized QE to pull market interest rates down by reducing long-term market yields through the purchase of long-term government securities and risky assets from the market, thus reducing the term and risk premiums. Due to the large scale of the asset purchases, policymakers -particularly in Latin America and Asia- maintain that the QE gave rise to a significant increase in global liquidity which led to destabilising capital inflows into many emerging economies (Borio, 2011; Ahmed and Zlate, 2014; Barroso et al., 2015; Chen et al., 2015). They argue that the massive capital inflows have increased the macroeconomic and financial market instability due to higher fluctuations in the exchange rates, asset prices, and inflation rates.

If inflows are large, there is an increasing demand for capital and financial assets in domestic markets which, pushes asset prices up. The large inflows also instigate domestic currency appreciation which is disadvantageous for export competitiveness. In this situation, monetary authorities face a policy dilemma: whether to contain inflationary pressures by increasing domestic policy rate or to avoid further inflows by lowering policy rate. Increasing the rate in times of massive inflows will more likely invite further unstable inflows leading to more inflationary pressures, unless some capital flows management policies are implemented. Hence, monetary authorities may opt to lower the domestic interest rate. This dilemma suggests that if the domestic financial market is open, the loose monetary policies of advanced major economies during QE may loosen monetary policy everywhere else, particularly in the emerging economies, thus generating a sequence of monetary policy contagious effect across the world.

In order to investigate the impact of QE, the second chapter utilizes a Global Vector Auto Regression (GVAR) framework due to Pesaran et al. (2004). The dataset we use is a monthly data for industrial production, consumer price index, stock price, exchange market pressure, short rates, and long rates in 17 advanced and 12 emerging economies from January 1995 to February 2015. Impulse responses, forecast error variance decompositions, and counterfactual analyses are utilized to evaluate the implication of US QE on the global economic conditions and monetary policymaking.

Although some studies have attempted to analyse the effect of QE on the global economy, their choices of US QE measurement neglect the actual intensity of QE market operations which is indicated by the massive expansion of the Federal Reserve balance sheet. For instance, Chen et al. (2015) assumes the reduction of US term or corporate spreads as the proxy for the magnitude of QE. We argue that these spreads do not fully represent the extent of real market QE operations, thus risking a misleading conclusion about the impact of QE. The increasing magnitude of the Federal Reserve balance sheet was often not fully followed by the term spread reduction due to the following: (1) term premium is merely an indirect target of the QE, not a direct instrument the Federal Reserve uses in operating the QE; and (2) the term premium fluctuations are not affected only by the QE, but also by other factors which the Federal Reserve cannot control completely. Considering the Federal Reserve balance sheet as a measurement of QE is also important because the QE unwinding (the reverse policy action of the QE) is also going to be operated by the Federal Reserve balance sheet reduction, also through open market operations. Moreover, according to Fratzscher et al. (2013), the Federal Reserve's actual QE operations is important and had a comparatively larger effect than the QE announcement.

Our challenge is then to correctly measure the magnitude of the US monetary policy stance when the policy rate hits the zero lower bound, and the QE is implemented. Our strategy to overcome this problem is to utilize a combination of 23 variables from a set of US monthly data series from McCracken and Ng (2015) and then utilize the principal component analysis to produce a single US monetary policy variable that best captures common factors behind the movement of the variables. Each of our 23 chosen variables represents one of these three categories of US monetary policy or condition, i.e. (a) monetary base; (b) policy rates and yields; and (c) spreads. We extract the principal component of the US monetary policy variable in two steps in order to maintain the short run dynamics particularly in the spread variables and be reflected in the principal component series. First, we extract the (first) principal component from each of the three groups. Therefore, we have three series where the first series represents the US monetary base conditions, the second represents yields, and the third represents spreads. We then extract the (first) principal component from the said three series to come up with our monetary policy measurement.

Our second contribution is regarding how the weighting matrix is developed. Chen et al. (2015) constructs a same matrix for the construction of all foreign variables in all country models. Our study utilises two distinct matrices for two groups of variables. In particular, the trade matrix is used as weighting matrix for variables that we consider as real variables: industrial productions and price indexes, while the financial matrix is used for financial variables: interest rates, stock prices, and exchange market pressure. The using of financial matrices for financial variables reflects the fact that domestic financial variables are more susceptible to the fluctuations of cross-border bilateral ownership of financial assets, instead of from trade relationships, and *vice versa*. Moreover, there are differences in response timing of financial and real variables, with financial variables respond to shocks more swiftly than real variables. Thus, by differentiating the weighting matrices for the construction of different foreign variables, we capture the channel of contagion better for each variable.

We find an asymmetric impact of the three QE episodes, with QE1 having the most substantial positive impact on the US, the other advanced and emerging economies compared to QE2 and QE3. QE1 appears to have been successful in halting recession periods following the global financial crisis in the global economy by increasing industrial production, stock prices, and price levels in all groups of economies. The results show the effectiveness of QE1 in reducing the long-term rates not only in the US economy as expected, but also in most other economies. This finding suggests that there has been a significant policy spillover of term and risk premium from the US to the global economy through long rates. There is also a tendency of monetary policy contagion through the short rates as accommodative monetary policy moves by the Federal Reserve tend to be trailed by lower monetary policy rates everywhere else. As the positive impact of QE1 begins to come into effect, inflationary pressures seem to increase particularly in the emerging economies. Hence, when QE2 and QE3 were implemented, the contagion of the short and long-term interest rates from the US to the economy were not as strong. During this period, domestic inflationary pressure appears to be the more pressing concern for emerging economies. Thus these economies opted to increase domestic rates and possibly had to deal with the potential for more inflows using other measures, such as capital flows management or macroprudential policy.

The third chapter develops an open economy, two-sector Dynamic Stochastic General Equilibrium (DSGE) framework featuring financial frictions *à la* Bernanke et al. (1999) to examine theoretically the findings in the second chapter. Although some studies have attempted to analyse the impact of the US QE on the global economy in a DSGE framework (see, for example, Haberis and Lipinska (2012) and Alpanda and Kabaca (2015)), these studies fail to consider the implications of US QE on monetary policymaking particularly in the emerging economies: something we find empirically significant in the second chapter. This finding and the analyses on the policy response by the emerging economies have important policy implications. First, if the implementation of monetary policy by a centre economy alters monetary policymaking in the other economy, even after adopting a flexible exchange rate regime, then monetary policy in periphery economies may not be as independent as suggested by standard open economy macroeconomic theories. Second, if the cross-border monetary policy spillovers from the core country exist and are significant, then monetary policymakers should increasingly become aware of the global dimension of their tasks, and thus need to internalise each others' economic condition and policy stances in policymaking as suggested by Borio (2011) and Caruana (2012). This chapter attempts to address these omissions. In particular, we utilize a DSGE framework to trace out how this policy contagion materialises in order to understand the reason behind the policy stance pursued by emerging economies, and then discuss the ramifications of such policy stance.

In this chapter, we firstly study the implication of monetary policy relaxation in the centre economy on the macroeconomic and financial stability of the emerging economy. We then discuss how the common features of a typical small open emerging economy, such as financial friction and liability dollarization, may exacerbate the impact of a foreign policy shock on the domestic economy. Subsequently, this chapter traces the implication of a monetary easing response by the small economy following the US monetary easing as observed particularly following the first round of QE.

The economy in the model is "small" in the sense that it can be affected by the rest of the world, but not *vice versa*. It is also "open" as it embeds households that engage in the international risk-sharing activity through international bond holdings and firms that borrow foreign currency to fund their investments. A large amount of foreign currency denominated borrowing is typical of emerging market economies -also known as the "liability dollarization" problem- which exposes the country to risks related to exchange rate fluctuations and shifts in investors' confidence. In the economy, there are also firms that export to the rest of the world, making them dependent on global demand and the international price for its product. Also, the fluctuation of its domestic currency adds more risks to the export goods' competitiveness, and thus affects internal macroeconomic stability. In addition to liability dollarization, the domestic financial market in this economy also exhibits financial market imperfections via the inability of investors to examine the investment results by borrowers. In order to cover the risks of asymmetric information, there is an external risk premium which raises the costs of obtaining external funds above internal one. This external finance premium is linked to the leverage ratio and the net worth (i.e. collateral) of the borrowers.

Our results indicate that a foreign monetary policy reduction widens the wedge between domestic and foreign interest rates, increasing capital inflows to the emerging economy and inducing a domestic currency appreciation. The currency appreciation makes the cost of investment in domestic economy cheaper and thus increase foreign borrowing by entrepreneurs. As the external finance premium decreases, domestic entrepreneurs take more risks by borrowing more and then invest more in capital production. This is in line with the international risk-taking channel of monetary policy (Bruno and Shin, 2015a), which maintains that, a domestic currency appreciation following a centre country monetary easing makes lending in foreign currency cheaper. Thus, domestic credit providers take more risks by providing more lending in foreign currency. Although lower foreign interest rates appear to profit entrepreneurs, the production of export goods reduces due to lower export product competitiveness following currency appreciation.

The implications of a responsive domestic monetary policy easing depend on the scale of the liability dollarization problem and the ratio of the capital-intensive sector to the rest of the economy. A domestic monetary policy reduction appears to be able to slow down capital inflows, which is desirable when capital inflows are destabilising and mainly go to financial markets such as stocks or bonds. If capital inflows are the source of funding for capital investment projects however, the effect of domestic monetary easing can be detrimental. Hence, the entrepreneurs' high dependency on foreign lending makes capital production sensitive to changes in interest rate differential and exchange rate fluctuations. Moreover, the effect is worse to the rest of the economy if the relative size of the capital-intensive sector is immense. Nevertheless, a responsive monetary easing reduces inflation rate. Thus, if inflationary pressures and asset price bubbles following the foreign interest rate reduction are the pressing concern, then responsive monetary relaxation might ease the pressure of the foreign monetary policy on the domestic economy.

These findings underline the reason behind domestic monetary policy easing response by emerging monetary authorities following substantial monetary relaxation by the centre economy: the domestic policy stance is expected to reduce destabilizing capital inflows, avoid domestic currency appreciation, and ease the domestic inflationary pressures. Nevertheless, this policy stance has negative consequences if the inflows is used for capital investment project and the capital-intensive sector is immense in the economy. Hence, an emerging economy might need to consider alternative policy measures to strengthen domestic economy against foreign financial and policy spillover, for instance by implementing macroprudential policy, as analysed thoroughly in the next chapter.

Contrary to the second and third chapters, the fourth chapter focuses on the reverse policy action, the Federal Reserve lift-off, where the US policy rate is increased and the near-zero interest rate policy is ended. The first rise in December 2015 showed that the US interest rate rise was led to a substantial withdrawal of capital from emerging economies. Although the significance of the Fed lift-off is well-understood in policy circles, there is, as yet, no systematic analysis of how best a country can respond to an external shock of the kind. This chapter contributes in this respect by studying the implication of Fed lift-off on emerging economies with different levels of financial integration, the exchange rate regimes, and the degree of financial developments. We then propose a set of macroprudential policy measures and systematically evaluate the effectiveness of each measure in the domestic economy's defence against the foreign rate rise. Subsequently, we analyse whether the level of financial integration, the type of exchange rate regime and the degree of financial development alter the effectiveness of macroprudential policies. As a measure of effectiveness, we calculate the volatilities of leading macroeconomic and financial variables and examine whether a combination of monetary policy with a particular macroprudential policy is effective in dampening fluctuations in those variables.

In this fourth chapter, we expand the scope of the third chapter in several directions: (a) it is a two-country advanced-emerging DSGE model; (b) it features financial institutions *á la* Gertler and Karadi (2011) and incorporates interactions between global and local banks; (c) it enlarges the policy armoury of the emerging economy by establishing a set of macroprudential policies and considering fixed exchange rates. In the model, the global banks in the advanced economy receive deposits from the advanced economy's households. These banks then use the deposits together with their own net worth to invest in the advanced economy's capital production and the emerging market banks. The local banks in the emerging economy use the funds from the global banks together with their own net worth to fund domestic capital production. This cross-border bank lending and borrowing is the *global liquidity* which serves as a key channel for the international propagation of shocks from the advanced to the emerging economy, linking monetary policy in the centre economy with capital flows into the recipient economies. The emerging economy implements a standard monetary policy rule and macroprudential policy measures to maintain domestic stability. The macroprudential measures are tied to a range of financial indicators (i.e. the loan-to-GDP ratio, leverage ratio, credit growth, and foreign banking borrowing) as their bases for the macroprudential tax/subsidy, focusing on lender's side restrictions. The lender-side of macroprudential policies tackle key externalities and market failures, directly affecting financial institutions' ability and willingness to lend to the real sector.

We find that an emerging economy with lower financial integration experiences a smaller reduction in the foreign liquidity flows, thus less reduction in aggregate credit to the real sector. Although being a less financially integrated economy appears beneficial in this situation, impediments to capital mobility hold back this economy from reaping the benefits of financial integration in the long run, as their steady state cross-border borrowing rate is higher and capital inflows in the banking sector is lower. We find that monetary policy combined with the macroprudential policy that targets foreign banking capital inflows performs best in most scenarios, suggesting that a policy that focuses on the main channel of cross-border monetary spillovers is preferable. The effectiveness of macroprudential policy improves under restricted capital mobility, reducing fluctuations in most financial variables quite significantly. The choice of the exchange rate regime also plays a crucial role in the impact of the Fed lift-off on the domestic outcomes, with the unfavourable impact of the foreign interest rate rise on the domestic outcomes more significant under a fixed exchange rate regime. Interestingly, however, limiting the exchange rate flexibility improves the effectiveness of macroprudential policy. In sum, our results highlight the importance of adopting a combination of policies against global financial disturbances including macroprudential measures, restrictions to capital flows, and restricting exchange rate flexibility.

Following the study on the role of the global-local banks interactions on the global liquidity dynamics in the fourth chapter, the fifth chapter focuses on the empirical regularity on the crucial role of international banks in providing the global liquidity, a condition the Bank for International Settlements (BIS) generally defines as a 'global ease of financing'. Our research objective is to examine how the activities of global banks and monetary policy decisions by the centre economy affect global liquidity and facilitate spillovers across borders. The results of the study hold some significant policy implications. The understanding of the drivers and ramifications of the aggregate global liquidity is vital for successful macroeconomic management. In particular, knowing the origin of global liquidity dynamics in any circumstances prompts more accurate policy recommendations. The global banks' connectedness map that we establish can also inform policymakers with a bigger picture of the cross-border international banking connection. In particular, it reveals which countries or groups of countries are important in this interconnection, implying that a banking problem in the particular countries or groups of countries may generate massive global consequences. Another critical policy implication is that, if the cross-border liquidity spillover is substantial, the extent to which domestic monetary policy can affect the domestic economy is jeopardized by the intense influence from foreign monetary conditions. For instance, an *expansionary* external monetary spillover may undermine the channel of domestic monetary policy transmission that is directed towards *contractionary* stance. On the other hand, an expansionary spillover may exaggerate a domestic expansionary monetary policy.

The current empirical literature on the decision of the volume and direction of cross-border bank lending often focuses on a small number of countries and is even limited to particular banks (see, for example, Galema et al. (2016), Cetorelli and Goldberg (2012a), Cetorelli and

Goldberg (2012c), Haas and Lelyveld (2014), Frey and Kerl (2015)). Although it is important to comprehend how international banks make international decisions to manage liquidity within a limited number of countries, an understanding of the problem from an aggregate global scale can shed more light on how the connections materialise among a large set of countries. Our study attempts to fill this gap by drawing a helicopter view of banking interconnection across the globe.

To study the determinants of global liquidity dynamics, we utilize a Vector Auto Regression (VAR) framework on the global liquidity, US monetary policy, US Dollar value against major trading partners, T-Bill Euro Dollar (TED) spread, and the global credit-to-GDP gaps. Then we establish a network connectedness map of cross-border banking dynamics across economies by utilizing the Bank for International Settlements (BIS) Locational Banking Statistics (LBS) of 35 countries and offshore financial centres from the fourth quarter of 2003 to the third quarter of 2016. We first use the GVAR to produce the forecast error variance decomposition (FEVD). Then we utilize the FEVD to build the global banks' connectedness network using the Diebold and Yilmaz (2009) method. To the best of our knowledge, this study is the first to use the BIS LBS in a GVAR framework. Our other novelty is that: we are the first to exploit the BIS LBS to establish the global banking connectedness networks and draw them into layered graph presentation. The layered graph presentation allows us to rank countries (or groups of countries) -represented by nodes- neatly according to their degree of importance, with the top node being the most influential.

The impulse responses show that the US monetary policy rate, US Dollar, global credit-to-GDP gaps, and TED spread are all significant determinants for the global liquidity variable at the 90% confidence level. On impact, positive shocks to the US policy rate and global credit to-GDP gaps increase global liquidity, while an appreciation of the US Dollar and an increase in the TED spread have the opposite effect. A positive shock to the US monetary policy rate significantly increases global aggregate cross-border lending on impact with maximum effect in 1.5 years, but the effect become negative in around 2.5 years. This increase in global liquidity seems to be dominated by higher cross-border banking lending to the US banking system following higher US interest rate expectation. This conjecture is supported by the USD appreciation in the medium term following the same positive US policy rate shock. The global credit-to-GDP gaps is a proxy for global banks' capital position and their willingness to take risks from lending to the non-financial sector. A higher global credit extension to the real sector is associated with higher global cross-border banking lending, and the effect is significant on impact for around two years after the shock, which implies that the worldwide banks' willingness to extend credit to the real sector is associated with a higher cross-border supply of funds and *vice versa*. The TED spread variable is a proxy for credit risk of the counterparty, where a larger TED spread indicates higher credit risk and thus tighter interbank market condition. A positive shock to the TED spread is associated with significant lower global liquidity. This result shows that a higher perception on counterparty banks' credit risks causes a significant reduction in the cross-border banking lending internationally with the strong effect remaining until around two years post the shock. A USD depreciation causes global liquidity to increase, which supports the international transmission via the 'risk-taking channel', where a cheaper dollar tends to cause international banks to take more risk and, thus, to lend more.

Our cross-border banking connectedness network shows that the globally aggregated *within* connectedness measure recedes overtime, while the spillover effects tend to grow, suggesting that the international transmission of banking shocks occurs gradually. US monetary policy is the most significant net transmitter of cross-border banking position across the globe, followed by the value of the US Dollar, and the aggregate global liquidity variable. This result once again underlines the significance of the US policy stance in determining the global banking liquidity. The groups of economies ordered by their degree of systemically significant financial institutions in the global banking system are the advanced economy group, followed by the Eurozone, the offshore financial centres, and the emerging countries group. This finding implies that emerging economies group is the most prone to shocks from external monetary conditions. This group is even less important than the offshore financial centres' group in the global banking interconnection. When we analyse the data in the country level, among the economies with the largest cross-border banking positions, the USA is the globally most influential, followed by France, Germany, the United Kingdom, and Australia. Japan is the least influential among the major economies even though it continues to be the largest net lender globally.

Chapter 2

US Quantitative Easing and the Global Monetary Policymaking

2.1 Introduction

This paper empirically analyses how the US Quantitative Easing (QE) affects the economic and financial condition of the US economy, the other advanced, and emerging economies; and whether it alters monetary policymaking in non-US economies. This research question brings about an important implication to theoretical research in open economy macroeconomics. If the implementation of monetary policy by a core economy is able to alter monetary policymaking in the other economies with flexible exchange rate regime, then monetary policy in periphery economies may not be as independent as suggested by standard open economy macroeconomic theory.

There are two major challenges in this study. The first challenge is related on how to effectively measure the extent of US monetary policy on the zero lower bound. Secondly, in order to model the international connectedness and contagions, we need to work with 6 macroeconomic variables from each of 29 countries and 3 global variables. Thus we have to deal with a dimensionality problem due to the large number of variables involved which makes it practically problematic to use a regular vector auto-regression framework in the study.

In order to tackle the first difficulty, we use a principal component analysis of 23 US monetary variables to construct a variable that measures the extent of QE as the conventional Fed Fund policy rate stays on the zero lower bound. The objective of using principal component analysis is to extract the common component across the 23 US monetary variables as the component is mainly driven by the extent of QE implementation. Using a consistent way to measure the extent of the QE is the challenge faced by empirical studies in the era of quantitative monetary policy. Including QE policy in a dataset that is started way before the QE era is problematic simply because the policy has not been implemented before. There is in principle a number of ways to measure QE. First, one can use event studies to study the impact of QE announcement on the financial market, such as (Gagnon et al., 2011; Fratzscher et al., 2013; Bauer and Neely, 2014). However, the announcement effect may only last for a short period -thus, more suitable for research on daily financial data- and may not capture the size of real market operation performed by the Federal Reserve. Second, one can use the Federal Reserve balance sheet size as an indication of Federal Reserve real market intervention. However, the Federal Reserve balance sheet is almost constant for the whole period before the QE era which makes it difficult to produce meaningful empirical results as there is no dynamics that could explain the relationship between balance sheet size and macroeconomic variables. Another way to measure the QE is by using the risk, corporate, or time spreads. The idea of using spreads as QE measurement lies on the fact that the Federal Reserve implemented the QE to reduce these spreads. By combining indicators of the US monetary policy stance into a single variable, this study aims to capture the common components that, we believe, are driven by QE.

The constructed monetary policy measurement is then used in a Global Vector Auto-Regression (GVAR) framework which we believe is the ideal model to tackle the second challenge concerning the dimensionality problem. The GVAR tackles dimensionality problem by constructing a set of "foreign variables" for each variable in each country model that is constructed according to the bilateral trade/financial pattern of an economic under consideration with the rests of the economies in the sample. Through the construction of the "foreign variables" we utilize a matrix of trade/financial bilateral relationships which define how the connectedness and contagions triggered by the US monetary policy materialize in the global economy. Using the GVAR model we are able to perform counterfactual analysis, impulse response analysis, and forecast error-variance decompositions in order to answer the research question on how the QE affects the global economy and financial condition and whether it alters global interest rate setting.

The reason why the QE was introduced was because the policy rate touched the zero lower bound. In the aftermath of the 2007/08 global financial crisis the Federal Reserve cut policy rates down from 5.25 in April 2007 to 0.25 in December 2008 since when the Fed Fund Rate becomes mute in indicating the extent of monetary policy. The Federal Reserve then introduced QE which affects its balance sheet size and composition. The US QE involves a massive amount of USD 3.5 trillion until early 2015, resulting in approximately 750 percent increase in the size of the Federal Reserve balance sheet. The enlargement of the Federal Reserve balance sheet materializes in three sequences: QE1 started in late November 2008 when the Federal Reserve decided to buy USD 600 billion in mortgage-backed securities (MBS); QE2 began in November 2010 with the Federal Reserve buying USD 600 billion of treasury securities; and QE3 began in June 2012 with the Fed buying on a monthly basis USD40 billion worth of MBS and USD85 billion of treasury and agency bonds starting in December 2012.

The QE was aimed at pulling the nominal market interest rates down by reducing long-term market yields through its purchase of longer-term government securities in the market, and thus reducing term premium. In addition, it can also reduce the risk premium of risky assets over Treasury securities by acquiring risky assets from the markets (Blinder, 2010). These operations can be performed by the authority through (a) the selling of the Treasury securities from its balance sheet, i.e. changing the composition of its balance sheet; and/or (b) creating new base money, i.e. expanding the size of its balance sheet.

The channels through which the QE may influence international economies is through the announcement effects and by expanding the global liquidity facilitated by the increasing interconnection of the global financial markets. Earlier studies argue that the additional global liquidity from the QE has resulted in an increase of capital inflows in most of emerging economies, particularly Latin America and Asia (Borio, 2011; Ahmed and Zlate, 2014; Chen et al., 2015; Barroso et al., 2015). The massive capital inflows have increased the macroeconomic and financial market instability due to higher fluctuations in the exchange rates, asset prices, and inflation rates. Extending beyond the QE, earlier studies also find that US monetary policy announcements have significant efect on US stock prices Bernanke and Kuttner (2005), and also on the international stock markets (Conover et al., 1999; Didier et al., 2012; Madeira and Madeira, 2015).

To address the increasing vulnerability emanating from volatile flows, the government of many emerging economies resorted to a combination of monetary policy, capital flows management, and a wide range of macroprudential measures. Monetary policy alone is not sufficient, because in times of large inflows, prices tend to increase and monetary authorities face policy dilemma whether to contain inflationary pressures by increasing policy rates, or accommodate by lowering their policy rate in order to avoid further inflows. Increasing rates in times of large inflows will more likely invite further unstable inflows, unless some capital flows management policies are implemented. This suggests that if domestic market is open and exchange rate volatility is reduced by intervention, the loose monetary policies of advanced major economies during the QE may instigate loose monetary policy stances everywhere else, particularly in the emerging economies, thus generating a sequence of monetary policy contagious effect across the world. If this is true, then monetary policy is not independent in emerging economies.

Gray (2013) notes that the contagion in monetary policymaking is in fact not a new phenomenon. He shows that there is a tendency for monetary policy stances of the countries to follow each other going back at least to the last two decades (Figure 2.1). This indicates that in addition to domestic variables like output gap and inflation target, global economic conditions and monetary policy stances of the other economies also play a major role in the monetary policy formulations of many countries.

There are at least three possible explanations for why a lower policy rate in one (centre) economy is more likely to induce lower rates in other economies. *First*, a decrease or expected decrease of interest rate in one major country will tend to depreciate its exchange rate towards others, which is undesirable for other countries due to the loss in their export competitiveness. Thus, one way to combat large appreciation is to cut policy rates (Gray, 2013; Taylor, 2013). Hofmann and Bogdanova (2012) suggest that international monetary policy spillover is a result of mutual resistance to higher instability due to capital inflows and exchange rate movement. *Second*, as argued by Bruno and Shin (2015a), lower US dollar interest rates which cause an appreciation of exchange rates of the other economies increase banks' ability to lend more in US dollars to firms with the same level of local currency loan, thus increasing risk-taking behaviour in financial markets. The monetary authority will more likely be inclined to reduce interest rates in order to discourage firms and banks borrowing US dollars. *Third*, the global low policy rates may also have been caused by common global factors, like the increase in the Emerging Markets' (EMs') saving rate combined with the limitations in the available financial assets in EMs that might induce shortages in the global assets markets (Hofmann and Bogdanova, 2012).

If the monetary policy contagion exists and is significant, monetary policymakers should

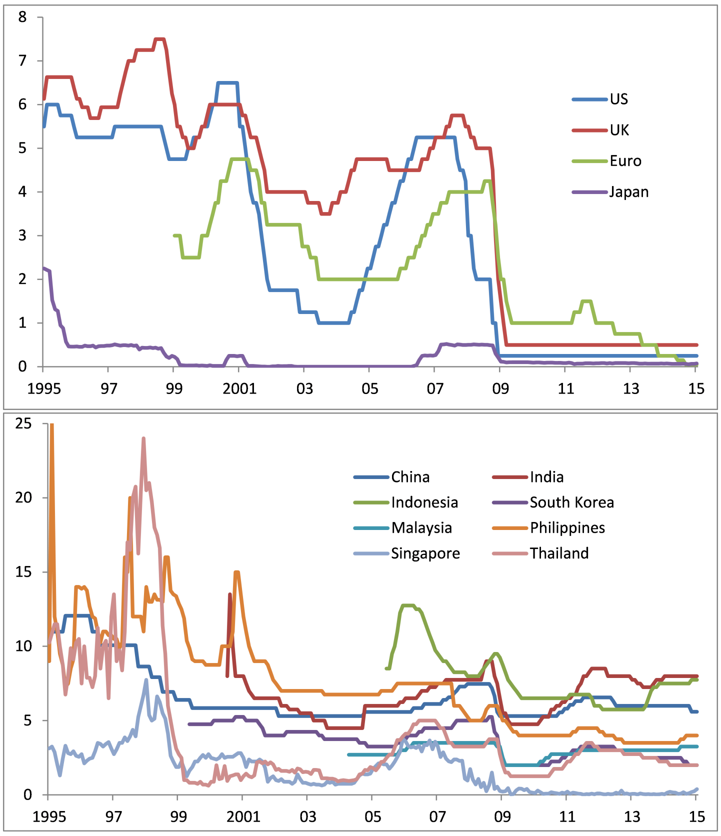


Figure 2.1: Monetary policy rates, Source: Datastream

increasingly become aware of the global dimension of their tasks, and thus need to internalize each other's economic condition and policy stances in policymaking as suggested by Borio (2011) and Caruana (2012). Taylor (2013) go even further by suggesting that there is a scope of the first-best solution for every country involved in an establishment of monetary policy coordination. Although monetary policy coordination across countries seems politically unfeasible, at least a second-best solution which is an internalization of each others' monetary policy stance is worth considering (Eichengreen, 2013; Taylor, 2013).

The extent to which the accommodative policy actions of the advanced economies (AEs) influenced the domestic and global economy, has been a source of growing interest in both academic and policy circles. With respect to the *domestic* impact of US QE, d'Amico et al. (2012) consider three channels through which the Large Scale Asset Purchase (LSAP) program affects the longer term US Treasury yields, i.e. the expectations or signalling channel, the scarcity or local supply channel, and the duration channel, and conclude that the LSAP has been effective in reducing the yield by about 35 to 45 basis point. On the real economy side, Chen et al. (2012a) using a medium-scale DSGE model find a modest impact of LSAP program on the US GDP growth and inflation with lasting impact on the level of GDP.

In general, studies show that US unconventional monetary policy has an asymmetric impact on the advanced and emerging economies (Chen et al., 2015; Eichengreen, 2013). Chen et al. (2015) who focus on the US term and corporate spreads as an intermediate target of QE find uneven distributions of benefits and costs of the QE, with the successful of the QE to avoid prolonged recessions and deflation in the advanced economies, but diverse impact on the emerging economies. Chinn (2013) underlines the macroeconomic challenges faced by emerging economies following the unconventional monetary policy particularly through the more volatile capital inflows and its impact on the exchange rates, but he casts doubt on unconventional monetary policy real positive impact on the advanced economies.

There are generally two distinct views on how the US QE has influenced the emerging economies. Some argue that the unprecedented accommodative monetary policy is necessary to recover the US economy in order to regain US product demands to emerging economies, thus allowing the emerging economies to recover as well (Lavigne et al., 2014). Others believe that a major proportion of the QE has contributed to a significant increase of capital inflows pressure to other countries, and then created a significant adverse spillover impact in the form of higher inflation, asset bubbles, risks of sudden stops, and export product competitiveness, especially to emerging Latin America and emerging Asia (Borio, 2011; Chen et al., 2015; Barroso et al., 2015; Ahmed and Zlate, 2014). Ahmed and Zlate (2014) find that the key drivers of net capital inflows to emerging economies are the growth differentials, interest rates differentials, and global risk aversion. Although most studies agree on the 'excessive' QE impact to emerging economies, they observe evidence of positive spillover through trade and confidence channel from countries that implement the QE especially on GDP recovery in emerging economies.

Our paper is closest to (Chua et al., 2013; Chen et al., 2015), which also use a GVAR to measure the impact of the QE. The main difference between our and these papers is on how the QE is identified. Chua et al. (2013) use the growth in US M2 as the indicator of US monetary policy which also includes the QE era. Chen et al. (2015) assumes the reduction of US term or corporate spreads to measure the magnitude QE. In particular, they conduct event studies near the Federal Reserve announcements to determine the magnitude of US term or corporate spreads reduction following the QE announcements, and subsequently use these to perform counterfactual analyses. We argue that the term spread may not fully describe the extent of real market operations associated with the QE as shown in Figure 2.2. As can be seen, the increasing magnitude of the Federal Reserve balance sheet, which is an indication

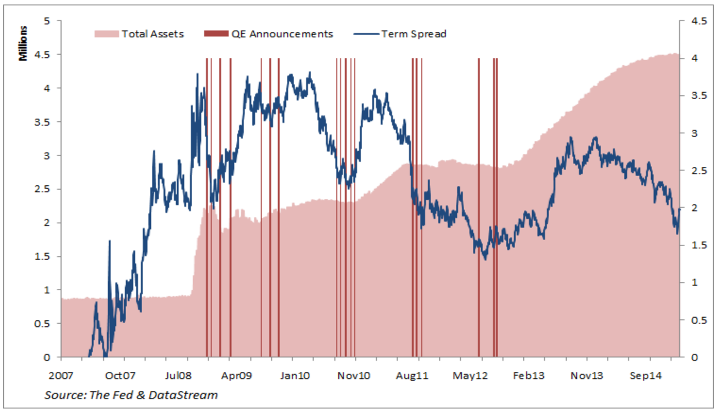


Figure 2.2: Term Spread 3 Months - 10 Years US T-Notes and Fed's Balance Sheet

Source: The term spread and T-Notes data is from Datastream, while the Fed's Balance Sheet is from The Federal Reserve website https://www.federalreserve.gov/data.htm.

of the QE market operation intensity, is often not fully followed by the reduction in the term spread due to the following: (1) term premium is merely an indirect target of the QE, thus it is not a direct instrument the Federal Reserve uses in implementing the QE; and (2) the term premium fluctuations are not affected only by the QE, but also by other factors, therefore the Federal Reserve cannot control the term premium completely.

Our study also differs from these studies in some other important respects. Regarding the weighting matrix construction, Chen et al. (2015) constructs the matrix by aggregating bilateral trade and capital flows together to come up with a single matrix. Therefore, they use the same matrix for the construction of all foreign variables in all country models. Chua et al. (2013) use only the portfolio flows to construct the weighting matrix. In our study, we use two different matrices for two groups of variables. In particular, the trade matrix is used as weighting matrix for variables that we consider real variables i.e. industrial productions and price indexes, while the financial matrix is used for financial variables i.e. interest rates, stock prices, and exchange market pressure. By differentiating the weighting matrices to use in constructing different foreign variables, we hope we are able to better capture which channel of contagion matters more for each variable. For instance, the using of financial matrices for financial variables reflects the fact that domestic financial variables in a country are more susceptible from the fluctuations of cross-border bilateral ownership of financial assets, instead of from trade relationships.

With regards to the global risk measurement, we define the global risk appetite by subtracting the CBOE VIX Volatility Index from the realized variance of S&P500, that is:

$$GRA = SP500 - VIX, \tag{2.1}$$

where GRA is the global risk appetite, $SP500$ is the realized variance of S&P500, and VIX is the CBOE VIX Volatility Index), while other studies use the CBOE VIX as volatility index. The reason why we use the method is that CBOE volatility index is the market expectations of near-term volatility, i.e. the implied volatility. Our global risk appetite variable is aimed at capturing the realized volatility in the market after the implied volatility is taken into account, therefore the risk appetite variable combines both the measurement of realized and implied volatility. As a robustness check, we also obtain GVAR results using CBOE VIX as one of global variables replacing our global risk measurement variable. It turns out that the results are not extremely different. Some other differences between our study and others relate to different dataset used and modelling specification, i.e. the countries included in the sample, the choices of macroeconomic variables, and some other specification issues concerning the GVAR modelling framework.

Another study that is close to ours is Olson and Young (2015) who also use the principal component analysis to construct the US monetary policy measurement. Our study differs from theirs in the scope of the study as they use Ordinary Least Square (OLS) to estimate the impact of US monetary policy innovations on the US domestic labour share, while our study is much broader as we consider cross-border effect of the QE on many countries and several macro variables. Secondly, we also differ on the choice of variables included in the US monetary policy measurement variable. In particular, they include some US private credits and loans variables, which we exclude from our US monetary policy measurement. We believe that although the amount of credits and loans are affected by US monetary policy, such variables are not directly linked to US monetary policy and are affected by many other macroeconomic variables like the domestic business cycle. In addition, we include some variables of US term and risk spreads, that do not enter in Olson and Young study. Our reason for including the US spreads variables is due to the importance of risks and term spreads as intermediate objectives of US QE which works through QE announcements and real market operations. To the best of our knowledge, our paper is the first to use the principal component-constructed US monetary policy variable in a GVAR framework.

2.2 Data and Methodology

2.2.1 Data and Measurement

This study uses monthly data from January 1995 to February 2015 (20 years). We include all countries with data available over this 20-year period, which comprises of 17 advanced economies and 12 emerging economies according to the IMF classification as follows:

Advanced economies: Australia, Austria, Belgium, Canada, France, Germany, Greece, Italy, Japan, South Korea, Netherlands, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States;

Emerging economies: Brazil, Chile, China, Hongkong, India, Indonesia, Malaysia, Mexico, the Philippines, South Africa, Thailand, Turkey.

Both the advanced and emerging economies groups possess reasonably wide geographical spreads and are thus geographically representative. In particular, the advanced economies group consists of the Americas, European, and Asian countries, while the emerging economies group comprises of some countries that belong to the Americas, Europe, Asia, and Africa. The total GDP Purchasing Power Parity (PPP) of these countries made up 79 percent of the world GDP PPP in the last twenty years according to the World Bank data.

The source of our data are Datastream, International Monetary Fund (IMF), The Organisation for Economic Co-operation and Development (OECD) Stat, the Federal Reserve Economic Data (FRED), and national sources. We use the seasonally adjusted logs of industrial production as an indicator of domestic real economic activity. For prices measurement, we use the logs of Consumer Price Index (CPI) for all items of goods from the IMF database where 2010 is the base year for all countries. The stock price data is the logs of real stock price index obtained from local currency stock prices which is available from Datastream for all countries.

The inclusion of the short-term interest rates variable is intended to represent the domestic monetary policy stance. Where possible, policy rates are used, but if data are incomplete, we use the domestic 3-month interbank interest rates as the proxy for policy rates based on the notion that the monetary authority can freely adjust it (Sousa and Zaghini, 2008). Most of the long rates are 10-year domestic government bond yields if available, or alternatively, shorter bond yields. Both the short and long-term interest rates data are transformed into monthly log of interest rates.

The Exchange Market Pressure Index (EMPI) variable is constructed in order to capture the intensity of external pressure that a country is exposed to, particularly as a result of capital flows pressures and global risks. We use the Real Effective Exchange Rates (REER), official reserve assets, and short-term interest rates to construct the index. The inclusion of official reserve asset into the EMPI is intended to capture the pressure to domestic exchange rate even if monetary authorities resist nominal exchange rate volatility. The EMPI here is constructed as a variation of the index proposed by Eichengreen et al. (1995): $EMP_t = 100(-w_{t,e}e_t - w_{t,res}res_t + w_{t,ir}ir_t)$ where $w_{t,X} = \frac{\sigma_{t,X}^{-1}}{\sigma_{t,e}^{-1}+\sigma_{t,res}^{-1}+\sigma_{t,ir}^{-1}}$ for $X = e, res, ir$; $e_t = log(E_t) - log(E_{t-12})$; $res_t = log(R_t) - log(R_{t-12})$; $ir_t = log(IR_t) - log(IR_{t-12})$; where E_t is the REER, R_t is the official international reserve assets, and IR_t is the short-term interest rates. σ_t is the standard deviation of the corresponding variable in the previous five years, for weights of the sixth year onwards. For weights of the first five years, the standard deviation computed from data covering the first five years is used. We use the inverse of standard deviation ($\sigma_{t,X}^{-1}$) to avoid the most volatile variable from dominating the index.

REER and official reserve assets enter the index as negative because exchange rate appreciation and higher official reserve assets position reflect lower exchange market pressure. In contrast, the log differenced of the short-term interest rates enters the index in positive because higher interest rates are observed when there is higher pressure to a country's money or credit market.

We include three global variables in our study, namely the US monetary policy variable, 'world financial oil' index, and global risk appetite variable. The US monetary policy variable is constructed by a method explained in Section 2.2.4.2. The world financial oil index is an average of Brent crude oil price and Datastream world financial index that describes the equity index of firms in financial sectors across the globe. The global risk appetite variable is constructed by subtracting the standardized CBOE VIX Volatility Index from the standardized realized variance of S&P500 . The CBOE VIX is a leading measure of market expectations of near-term volatility conveyed by S&P500 Index (SPX) option prices. Subtracting the VIX from the realized variance of S&P500 allows us to obtain the measure of market's appetite towards global financial risks which affects the pattern of capital flows fluctuations in the global economy. Figure 2.3 presents the plot of world financial oil and global risk appetite.

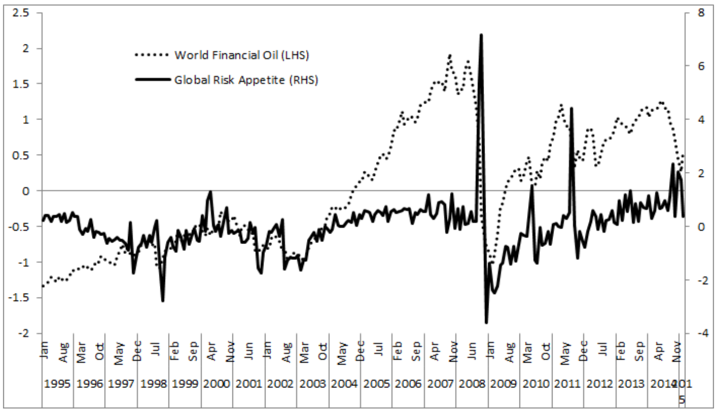


Figure 2.3: Global variables: World financial oil index and global risk appetite, Source: Datastream

Each variable is tested for the presence of a unit root by weighted symmetric Augmented Dickey-Fuller (ADF) tests. The unit root tests are implemented to each individual country variables, foreign variables, and global variables in order to check the integration order of up to I(2). Table 2.1 shows the order of the integration of every variables in every countries' models. Stock price data are I(1) for all countries. Industrial production, price index, short term rate, and long term rate data is I(1) for more than 80% of the countries. For Mexico and Turkey, the price index are I(2). Only EMP which has higher percentage of countries with stationary EMP variable with only 30% of the countries' EMP are I(1). Because most of the data is integrated of order at least 1, we expect to observe cointegration among variables in a country model or cointegration between variables in different country models, which is useful for our Global Vector Error Correcting Model (GVECM) estimation as explained in the next sub section.

2.2.2 Global Vector Auto Regression (GVAR) / Global Vector Error Correcting Model (GVECM)

The GVAR, initially developed by Pesaran et al. (2004), is a macroeconometric model that exploits advances in the analysis of cointegration systems in order to perform analysis in a global modelling framework. The reason why we choose the GVAR in our study is because: (a) it tackles the dimensionality problem of our data which involves handling 29 countries, 6 domestic variables, 3 global variables, and 242 time points; (b) it allows the use of pre-defined matrices to impose the strength of bilateral relationship for each pair of countries in the study; and (c) it provides counterfactual analysis framework that allows us to study the impact of a policy by experimenting on what would be the outcomes of the macro variables if the policy was not implemented.

The GVAR tackles the dimensionality problem by constructing "foreign variables" for each variable in each country model that are constructed according to the bilateral trade/financial pattern of an economy under consideration with the rests of the economies in the sample. The country-specific equations are then estimated in VAR setting which involve domestic macroeconomic variables (e.g. industrial production, price index, interest rate, etc) together with the corresponding foreign variables. This country-specific model is then combined together with other country models comprehensively in the GVAR model to produce simultaneous forecasts or impulse response analysis for all variables of every country/region.

In our study we have 29 economies, indexed by $i = 0, 1, 2, ..., 28$. Country 0 is the reference country (USA). There is a vector of $\mathbf{x}_{it}$ of k_i domestic variables for each economy. $\mathbf{x}_{it}$ is the set of endogenous variables which for each economy include: industrial production (ip_{it}), consumer price index (pi_{it}), stock prices (sp_{it}), short-term interest rates (sr_{it}), long-term interest rates (lr_{it}), and exchange market pressure index (emp_{it}). Therefore we set $\mathbf{x}_{it} = (ip_{it}, cpi_{it}, sp_{it}, sr_{it}, lr_{it}, emp_{it})'$, so the number of the endogenous variable for each economy $k_i = 6$ or less, according to data availability. The k_i^* foreign variables of country i model are constructed as a weighted average of the corresponding variables belong to the other countries', weighted by country i international trade / financial pattern with the remaining countries in the sample:

$$\mathbf{x}_{it}^* = (ip_{it}^*, cpi_{it}^*, sp_{it}^*, sr_{it}^*, lr_{it}^*, emp_{it}^*)', \quad ip_{it}^* = \sum_{j=0}^{N} w_{ij}^{ip} ip_{jt} \tag{2.2}$$

Foreign variables are denoted with a star (*). The weights $(w_{ij}^{ip}, w_{ij}^{cpi}, w_{ij}^{sp}, w_{ij}^{sr}, w_{ij}^{lr}, w_{ij}^{emp})$ for i, $j = 0, 1, ..., N$, are based on trade and/or financial shares, i.e. the share of country j in the total trade or financial flows of country i with respect to total trade or financial shares of country i with the rest countries. For each economy, there is a VAR model containing a set of equations that relates the vector $\mathbf{x}_{it}$ of k_i domestic variables to the global economy via foreign variables $\mathbf{x}_{it}^*$ plus deterministic variables such as time trends and global exogenous variables (here, world financial oil and VIX index). The full derivation of the GVAR model is presented in the Appendix A.1. In general, the GVAR estimation is performed in two steps. *First*, for each economy a vector error correction model (VECM) is estimated using reduced regression techniques. Below is an example of the model which is a VECM with one lag.

$$\Delta \mathbf{x}_{it} = \mathbf{c}_{i0} - \boldsymbol{\alpha}_i \boldsymbol{\beta}_i' [\mathbf{z}_{i,t-1} - \boldsymbol{\gamma}_i (t-1)] + \boldsymbol{\Lambda}_{i0} \Delta \mathbf{x}_{it}^* + \boldsymbol{\Gamma}_i \Delta \mathbf{z}_{i,t-1} + \mathbf{u}_{i,t} \tag{2.3}$$

where $\mathbf{z}_{(i,t)} = (\mathbf{x}_{it}', \mathbf{x}_{it}^{*'})'$, $\boldsymbol{\alpha}_i$ is a $k_i \times r_i$ matrix of rank r_i, $\boldsymbol{\beta}_i$ is a $(k_i + k*_i) \times r_i$ matrix of rank r_i, and $\boldsymbol{\gamma}_i$ is the time trend coefficient. In this case, $\mathbf{x}_{it}^*$ are treated as 'long-run forcing' or I(1) weakly exogenous with respect to the parameters of the VARX* model. The VARX* model is estimated for each country separately conditional on $\mathbf{x}_{it}^*$.

Second, although estimation is done on a country by country basis, the GVAR model is solved for the world as a whole, i.e. in terms of a $k \times 1$ global variable vector, $k = \sum_{i=0}^{N} k_i$, taking account of the fact that all the variables are endogenous to the system as a whole. Through some derivations, the GVAR(p) model is obtained:

$$\mathbf{x}_t = \mathbf{b}_0 + \mathbf{b}_1 t + \mathbf{F}_1 \mathbf{x}_{t-1} + \cdots + \mathbf{F}_p \mathbf{x}_{t-p} + \boldsymbol{\varepsilon}_t. \tag{2.4}$$

This GVAR model is used for impulse response and conditional forecasting analysis[1]. It can be shown that the GVAR model associates domestic variables with the global economy via three distinct but inter-connected channels: (a) The direct relationship between $\mathbf{x}_{it}$ on $\mathbf{x}_{it}^*$ and its lagged values; (b) The relationship between $\mathbf{x}_{it}$ on $\mathbf{x}_{it}^*$ through the common global exogenous variables i.e. the oil price, world financial index, and volatility index; (c) Specific national or sectoral shocks; (d) Non-negligible contemporaneous dependence of shocks in country i on the shocks in country j, measured via the cross country covariances, $\boldsymbol{\Sigma}_{ij}$.

2.2.3 Specification and Estimation of the Country-Specific Models

Our study makes use of a set of domestic variables, which includes industrial productions, price indices, short-term interest rates, long-term interest rates, stock prices, and exchange market pressure indices, for each country's VARX model. However, not every country's model contains all these domestic variables for two reasons, (a) some data series are not available in some countries; and (b) the US model is specified differently due to the dominant role of the US economy and thus reflected in our model. All foreign variables enter the country-specific models in all country models, except for the US. For all non-US economies, all foreign variables enter into every country-specific model as weakly exogenous variables. In addition, the three

[1] We use the procedures provided in the GVAR Toolbox provided by Smith and Galesi (2014).

global variables, i.e. US monetary policy, world financial oil, and global risk appetite are also included in every VARX country model (except the US) as weakly exogenous.

The specification of the US country models is different from the rest to reflect the US's major role in the global economy and to measure the global impact of the US QE which is the objective of this study. For US country models, we exclude foreign short-term interest rates, foreign long-term interest rates spread, and foreign equity price, assuming that these foreign variables are more likely to be endogenous for the US economy. US monetary policy, world financial oil variable, and global risk appetite enter the US VARX models as endogenous.

The rank orders of the VARX models are estimated based on Johansen's trace statistic with some adjustments made according to the visual inspection of the persistence profiles. We restrict the trend coefficients to lie in the cointegrating space and leave the intercepts unrestricted (case IV in the GVAR toolbox and Pesaran et al. (2000)). The lag orders for the VARX models are determined by the Akaike Information Criterion (AIC) subject to a maximum lag order across models of 3 and 2 for $\mathbf{x}_{it}$ and $\mathbf{x}_{it}^{*}$, respectively. Specification tests related to the GVAR models have also been performed.

2.2.4 Constructing Weighting Matrices and US Monetary Policy Variable

2.2.4.1 Weighting Matrices

The construction of the weighting matrix is important in a GVAR model because the matrix defines how variables between two countries are related. The modelling of foreign variables provides a channel through which the variables in all other countries influence the corresponding variable of a country's model. Therefore, the construction of the weight matrix for country i should reflect this by means of assigning higher weights to a counterpart country with a higher trade or financial relationship, while lower weights should be given to less important counterpart countries.

It is common in GVAR studies to use the trade matrix for all the variables (including the financial variables). With the availability of the financial matrix, we would like to analyse whether the using of financial matrix in combination with the trade matrix improves our model. Hence, we compare the results produced by a GVAR model with trade matrix only and that with a combination of trade and financial matrices. The second model utilizes trade matrix to construct foreign variables for foreign industrial production and inflation variables for each country model, while the financial matrix is employed for foreign short term interest rate, long term interest rate, stock prices, and exchange market pressure index variables. In order to choose between the two competing weighting schemes, we compare the root mean squared forecast error (RMSFE) of the forecast variables and select a scheme which produces lower RMSFE as the benchmark weight:

$$RMSFE(h,n) = 100\sqrt{n^{-1}\sum_{t=T}^{T+n-1} e_t^2(h)}, \tag{2.5}$$

$$e_t(h) = \frac{(y_{t+h} - \hat{y}_{t+h|t})}{h}, \qquad h = 1, 2, \ldots, 12, \tag{2.6}$$

where y_{t+h} is the actual value and $\hat{y}_{t+h|t}$ is the forecast, h = forecast horizon, and n= size of forecast sample.

We calculate cross-country average RMSFE for each endogenous variable for the data series which we randomly choose to stop at June 2012 for 1-month to 12-months ahead forecasting horizon. As shown in Figures 2.4, the RMSFE results show that the trade-only and the trade-financial weighting scheme perform equally well in general. However, the cross-country RMSFE averages for the short term interest rate and long term interest rates models show that the trade-financial weighting is significantly superior compared to the trade-only weighting matrix. This result reflects the ability of the financial matrix to capture the fluctuations in the interest rates better than the trade matrix. For this reason, we use the trade-financial weighting matrix as our benchmark model.

Bilateral trade matrix is constructed as the summation of the export and import figures between two countries. The annual bilateral trade data is available from the IMF Direction of Trade Statistics (DOTS) for a period from 1998 to 2014. The trade matrix data is available for all countries in the sample. We take an average of the bilateral trade matrix throughout these periods to come up with a single trade matrix.

For the financial matrix, we take an average of the financial *liabilities* matrix and financial *asset* matrix. The two financial weighting matrices provide distinct interpretation on how one country's domestic variables are affected by the movements of the other country's domestic variables. The financial *liabilities* matrix which is the gross bilateral financial liabilities on

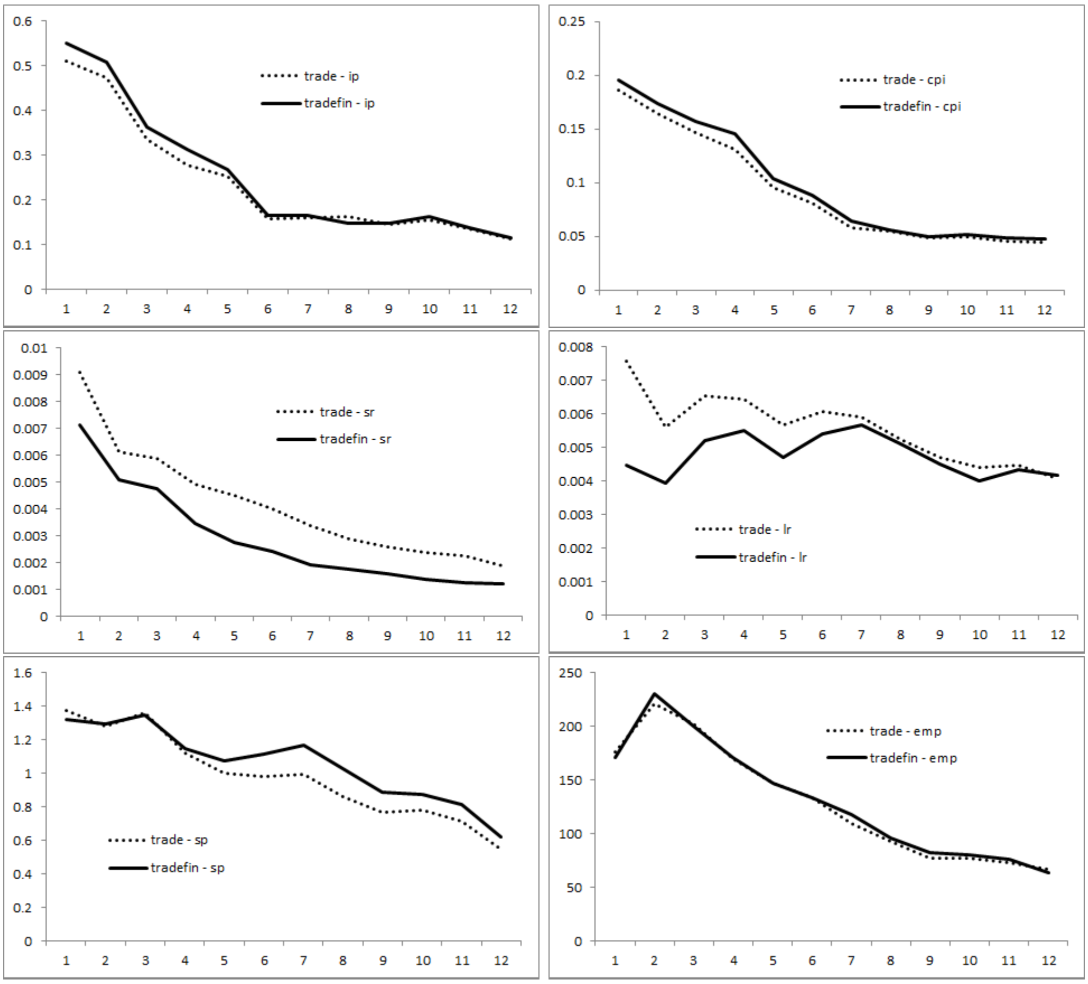


Figure 2.4: 1-month to 12-months ahead RMSFE comparison of two weight matrices schemes.

Note: The bold line represents RMSFE using trade-only weighting matrix, whereas the dotted line represents RMSFE using the combination of trade and financial weighting matrices. ip = industrial production; cpi = consumer price index; sr = short term interest rates; lr = long term interest rates; sp = stock prices; emp = exchange market pressures.

total inward portfolio equity and debt investment positions, and total inward direct investment positions to country i from the rest of the countries in the sample. Therefore, this liabilities-side (inward) financial matrix reveals the risks of foreign capital inflows fluctuations, e.g. sudden stops and large surges. The financial *assets* exposures is gross bilateral financial claims data on total outward portfolio equity and debt investment positions, and total outward direct investment positions of the country i to the rest of the countries in the sample. Thus, this weight indicates the risks emanating from fluctuations in asset valuation and default risks from financial investment abroad.

Both financial assets and liabilities matrices data are constructed using raw data from IMF Coordinated Direct Investment Positions (CDIS) and Coordinated Portfolio Investment Positions (CPIS). CDIS data is annual data that is available from 2009 to 2013, while CPIS data is from 2001 to 2014. The two financial matrices are averaged across available data period.

2.2.4.2 US Quantitative Easing Measurements

One of the main challenges in this area of study is measuring the magnitude of monetary policy stances when the central bank implements the QE. Traditionally monetary policy stances are reflected through the movement of the policy rate or the size of monetary aggregates. When the policy rate is bounded by the zero lower bound, the indicative stances of monetary policy through policy rates become practically unavailable. As the QE is implemented through the Federal Reserve balance sheet market operation, there is a scope to use the size of the Federal Reserve balance sheet as the measurement of the monetary stance during the QE. However, the use of only the Federal Reserve balance sheet as US QE measurement is problematic empirically because the balance sheet was almost constant before the QE but expand dramatically afterwards.

Our strategy to overcome this problem is to utilize a combination of some chosen US monetary series and then apply principal component analysis to produce a single US monetary policy variable that best captures common factors behind the movement of the chosen variables.

We first choose 23 variables from a set of US monthly data series from McCracken and Ng (2015). They develop FRED-MD[2], a macroeconomic database that contains 135 US monthly series obtained originally from Global Insights Basic Economics Database (GSI) and the Con-

[2] FRED-MD database can be obtained from http://research.stlouisfed.org/econ/mccracken/

ference Board. Each of our 23 chosen variables represents one of these three categories of US monetary policy or condition i.e. (a) monetary base; (b) policy rates and yields; and (c) spreads. The US monetary base series include all variables that describe the monetary size of the US economy like money stock, monetary base, and Fed's balance sheet. Monetary policy has long been associated with how the monetary authority controls the money supply in order to stimulate or restrain macroeconomic condition. Therefore, we believe that including measurements of nation-wide money stock in our benchmark US monetary policy measurement is essential. The inclusion of measurements of money base size and the Federal Reserve balance sheet is even more important in a US QE study because according to Fratzscher et al. (2013), the Fed's actual LSAP operations which are reflected in its balance sheet is important and had a comparatively larger effect than the Federal Reserve LSAP announcement.

The second group of our chosen variables contains the effective Fed funds rate (EFFR), 3-month to 10-year risk-free bonds yields, and high rating corporates yields. The EFFR was traditionally known as the sole indicator of monetary policy stance before the Zero Lower Bound (ZLB) but becomes effectively zero afterwards.

The third group contains spreads between various term yields and the Fed funds policy rate. We consider five term spreads i.e. spreads of the 3-month, 6-month, 1-year, 5-year, and 10-year risk-free government securities yields, all against the EFFR. In addition, we also include the risk spreads from the high-rating Aaa and Baa corporate bond yields to the EFFR. As Blinder (2010) points out, the Federal Reserve's effort to push down the risk premiums to stimulate credit and growth is of great relevance during the QE.

The full list of variables included in the US monetary policy variable is presented in Table 2.2. We take inverses of every series in the monetary base group (a) to be consistent with the other two groups where increases in the variables indicate policy contraction and decreases indicate accommodation. Figure 2.5 show the standardized values of variables included in our measurement of US monetary policy.

We use principal component analysis as a statistical procedure to reduce data dimension of a set of observable variables to construct the US monetary policy measurement variable. The explanation on principal component analysis is presented in Appendix A.2. We extract the principal component of the US monetary policy variable in two steps in order to maintain the short run dynamics particularly in the spread variables and be reflected in the principal

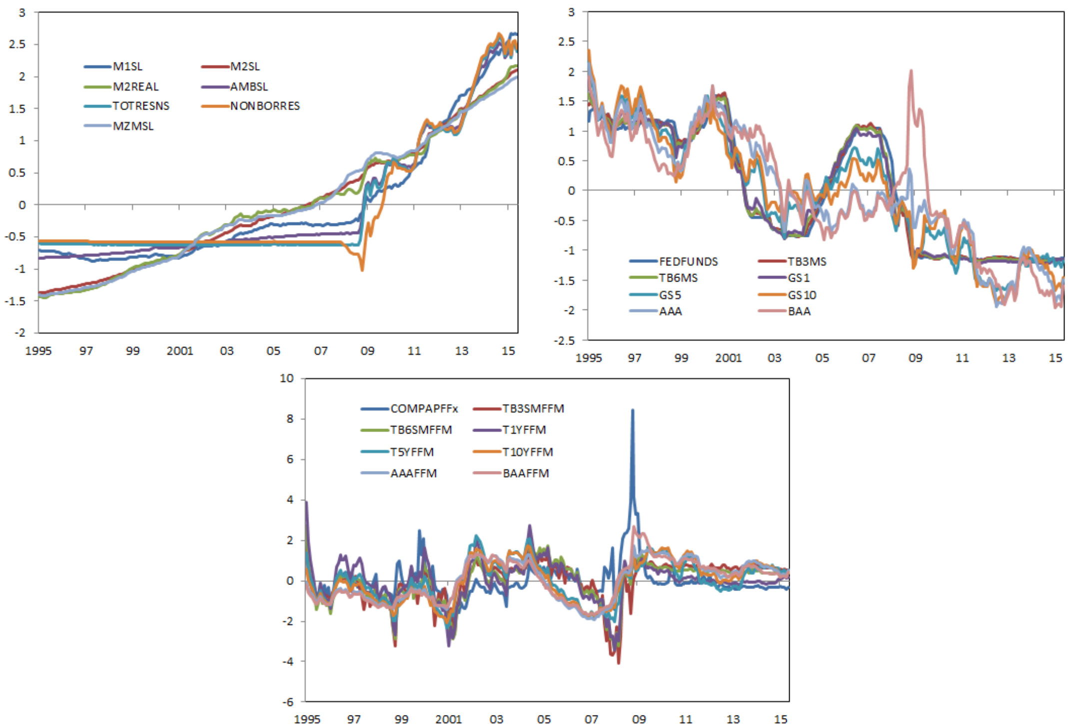


Figure 2.5: Standardized 23 US Monthly data series to construct our US monetary policy variable

Source: FRED-MD database from http://research.stlouisfed.org/econ/mccracken/ built by McCracken and Ng (2015).

component series. First, we extract the (first) principal component from each of the three groups. Therefore, we have three series where the first series represents the US monetary base conditions, the second represents yields, and the third represents spreads. We then extract the (first) principal component from the said three series to come up with our monetary policy measurement. The estimated US monetary policy variable is used from January 2009 when the ZLB period starts, while for prior to January 2009 the standardized US Effective Federal Fund Rate is utilized. The plot of our benchmark US monetary policy measurement variable along with the counterfactual paths is in Figure 2.6.

2.2.4.3 US Quantitative Easing Measurements: Counterfactual Paths

The counterfactual analyses compare an actual realized set of economic conditions with the same set of economic conditions under some pre-determined values in one or more variables that are imposed on the system. Thus, counterfactual analyses in the GVAR context are basically forecasting exercises conditional on a set of predetermined values in one or more variables. As we intend to analyze the outcome of some macroeconomic variables if QE was not implemented, we need to have counterfactual paths of US monetary policy in a particular period under the assumption of no QE implementation. The predetermined paths are then imposed to the GVAR system in order to obtain the paths of every other variable in the system within the same period. The full derivation of conditional forecasts is available at Appendix A.3.

To determine the counterfactual paths of the US monetary policy variable under the assumption of no QE implementation, we believe that we can rule out any increasing path because the increasing path is highly unlikely under counterfactual of no QE condition. In particular, we assume that US monetary base is at most constant under the no QE scenario. Similarly, under the no QE scenario, increasing US interest rates are highly unlikely even if the Fed took no action when the policy rate hit the zero lower bound, thus we assume that the set of US interest rates and yields are either constant or decreasing in the counterfactual scenario. Due to this consideration, we only consider two possible paths that may have been realized under the no QE scenario, i.e. the constant path which is the maximum possible path that could have happened if the Fed did not implement the QE and a decreasing path.

The counterfactual paths are presented in Figure 2.6. For the *constant* path, the level of

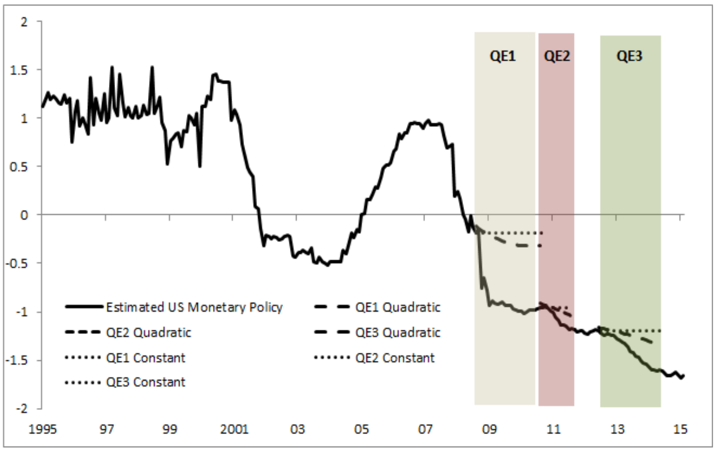


Figure 2.6: Counterfactual scenarios of the US monetary policy variable

the US monetary policy variable is assumed to remain at the same level in the month before the QE implementation up to 24 months for QE1 and QE3, and up to 12 months for QE2 due to the smaller and shorter period of QE2 implementation. For the *decreasing* path, there are many possible paths that we can choose from that can fit anywhere between the constant and the actual path. Our construction of the decreasing path is rather ad hoc. The idea is to reflect the immediate effect of QE and subsequently maintain the short run dynamics of the actual path. We estimate the actual path using the quadratic equation, then we increase the slope to produce the path. As can be observed in the result section, it turns out that the counterfactual results from imposing the two paths on the US monetary policy variables are not significantly different.

2.3 Estimation Results

2.3.1 Domestic and Cross-border Impact of the Three Periods of US QE: Counterfactual Analyses

The sets of counterfactual results are available from our GVAR analysis for each country in the sample. We then group the countries according to their level of economies and regions. In order to aggregate the country results, we take the cross-country averages of the counterfactual results for every variable and weight the results by these countries' 1990-2013 GDP, PPP (Purchasing Power Parity). For every figure in the counterfactual analyses, the solid lines plot the actual paths, the dotted lines are counterfactual paths of no QE scenario where the US monetary policy variable is assumed to be constant, and the dashed-lines are from the quadratic path.

2.3.1.1 Exchange Market Pressures

First thing to remark from our counterfactual graphs is that the difference between the constant and quadratic counterfactual paths for the US monetary policy measurement is not particularly significant. A second remark is that, in addition to the US QE, the European Central Bank (ECB) and the Bank of England (BoE) also introduced QE measures around the period of US QE. As a result, the result of our counterfactual analysis of the US QE impact on the global economy may to some extent is affected by the QE introduced by the ECB and BoE.

Figure 2.7 shows the counterfactual plots on EMP index to groups of economies, where increasing index indicates exchange market depreciation pressures and vice versa. Both the constant and quadratic monetary policy counterfactual analyses show that periods of US QE are associated with appreciation pressures in other economies which show the sign of capital inflows pressure, although there are some exceptions in each QE episode. In general, the appreciation pressures seem to have been experienced by the advanced and emerging economies alike as the counterfactual paths are higher in general compared to the actual paths. QE1 appears to cause the biggest appreciation pressures compared to the later QE episodes. For Latin American and advanced European countries, the exchange market appreciation pressures are delayed until around six months after QE1. The appreciation pressures reached the peak at around the fourth quarter of 2009.

Similarly, QE2 and QE3 also create appreciation pressures in all economies outside the US, except emerging Asia for QE2 and advanced Asia for QE3. What appears to happen in emerging Asia amidst QE2 is that, the governments of emerging Asia countries attempt to increase short-term policy rates in an attempt to curb inflationary pressures built up after QE1. As the short-term rates are included in the EMP index, the increasing domestic short rates in emerging Asia push up the EMP. The depreciation pressure for advanced Asia during QE3 is due to Japan's plan to expand the fiscal and monetary policy.

2.3.1.2 Stock Prices

Figure 2.8 shows the counterfactual plots on stock prices of the groups of economies. Our counterfactual analyses show that QE1 has been successful in recovering the stock markets in the US, other advanced economies, and emerging economies, which were adversely impacted

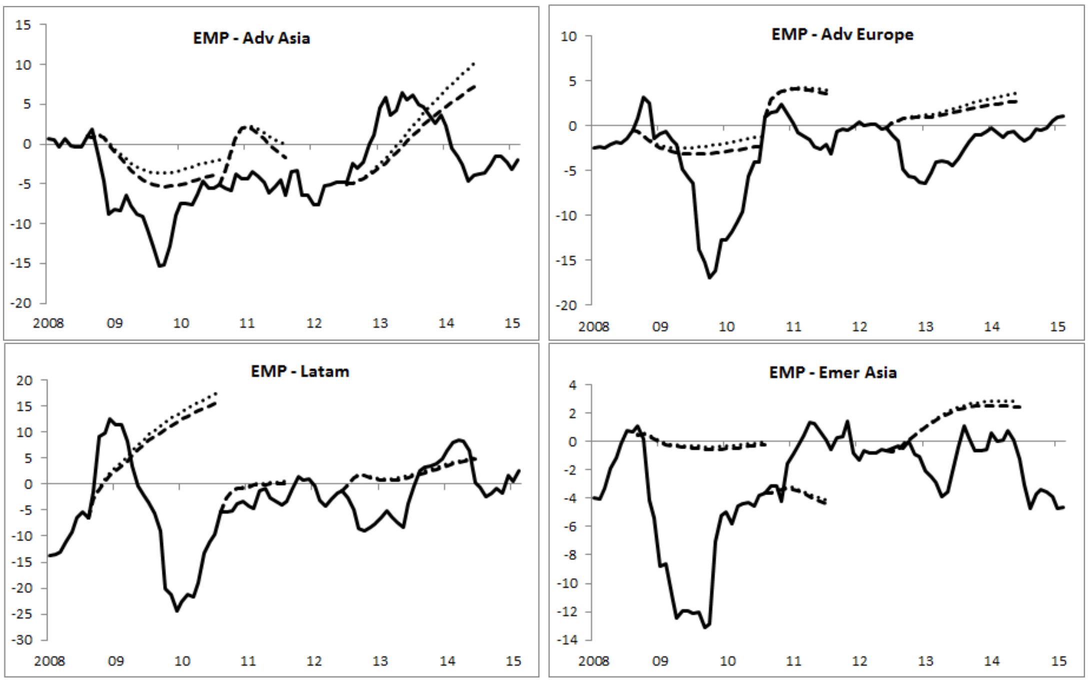


Figure 2.7: Conditional Forecasting - Exchange Market Pressures

by the global financial crisis in 2007. For the advanced Asian stock markets, although there has been an increase in stock market indices following QE1, our counterfactual calculation also produce plots similar to realized data. For other groups of economies, stock prices are more likely to remain subdued and even to decrease for a longer period in the absence of QE1 implementation. This finding indicates that the expansionary US QE policy is largely effective in boosting confidence in the domestic US stock market. Furthermore, as the global stock prices show a strong tendency to comove, the rebound of the US stock market confidence appears to spillover to the emerging and other advanced markets.

The impact of QE2 and QE3 in global stock markets is also quite positive in all groups of economies, although to a much lesser extent compared to QE1. QE3 appears to benefit all advanced stock markets in our data, i.e. the US, advanced Asia, the Euro Zone, and the UK stock markets. Emerging Asia, Latin America, and China seem to also benefit from the earlier phase of QE3 but the announcement of the tapering plan in mid-2013 affects market indices in these economies negatively through the intensified global risks, therefore the overall positive impact of QE3 is smaller in emerging economies.

The cross-border impact of QE to emerging economies' stock markets is more likely to occur through the signalling channel, where the indication delivered by the Federal Reserve to keep US interest rates low for a longer period is more likely to cause investors to search

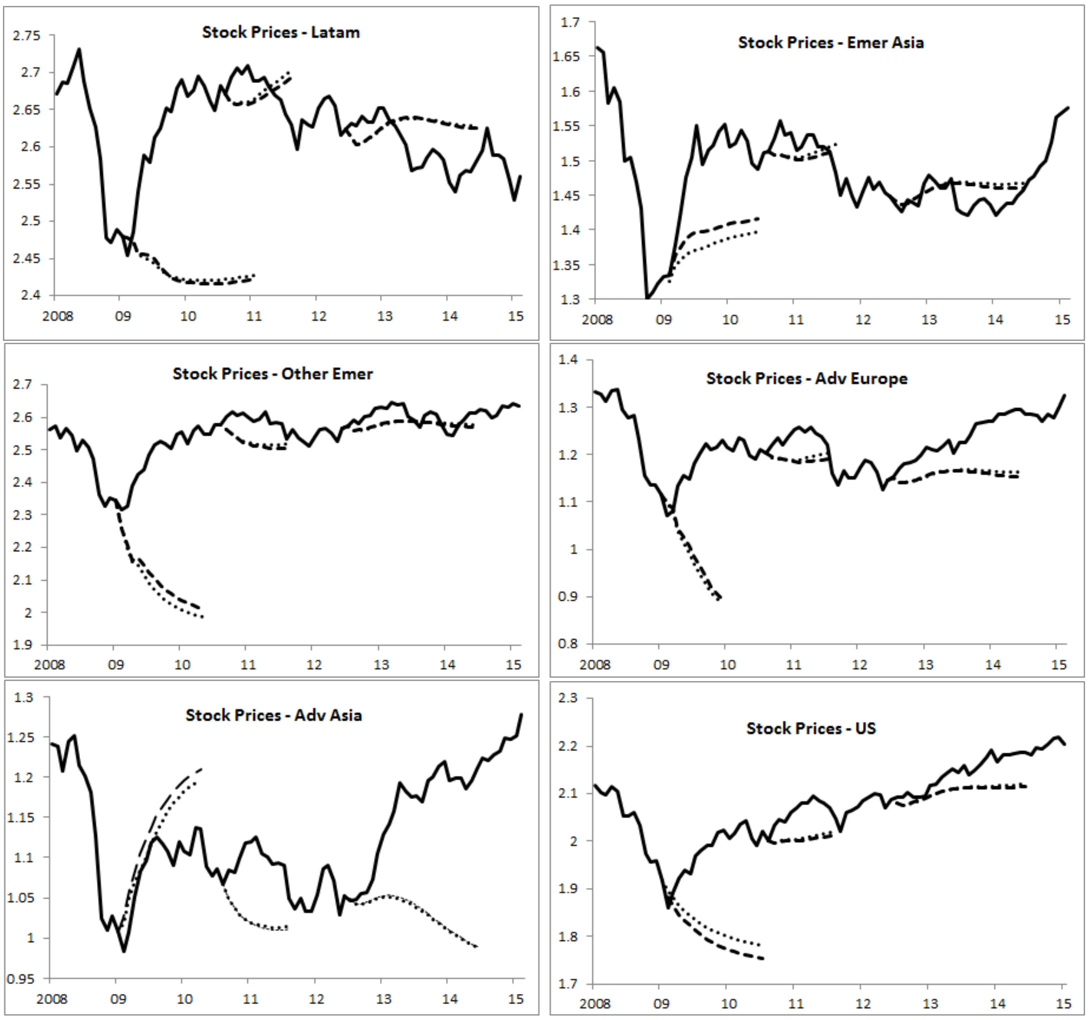


Figure 2.8: Conditional Forecasting - Stock Prices

for yields in overseas markets, including through riskier investment alternatives. Therefore, although the increase in stock indices is a sign of positive recovery in the financial markets, it may also be an indication of asset price inflation pressures due to higher demand for financial assets. The result supports earlier studies suggesting the significance of the US monetary policy announcement on the US stock prices such as Bernanke and Kuttner (2005) who find that, on average, a hypothetical unanticipated 25-basis-point cut in the federal funds rate target is associated with about a one percent increase in the US broad stock indexes. Moreover, the US monetary policy announcement is also an important factor for the international stock markets (Conover et al., 1999; Didier et al., 2012; Madeira and Madeira, 2015).

2.3.1.3 Price Indices

An observation of the counterfactual graphs indicates that QE1 has a considerably larger effect than the other QE episodes in the four groups of economies. The implementation of QE1 appears to be successful in discontinuing substantial deflationary phases following the global financial crisis as the actual paths are in general higher than the counterfactual paths. The impact of QE1 is particularly large for the US and advanced Europe as their counterfactual paths are largely stable making the discrepancies with the actual paths wide. In contrast, the divergence of the actual and counterfactual paths of the emerging Asia group is not as wide because the counterfactual paths are also increasing.

QE2 also has the same impact on price indices in the US, advanced Europe, and emerging Asia. Nonetheless, the impact of QE3 on price indices appears negligible everywhere, even for the US economy. Although a price indices upsurge subsequent to any recession periods is a sign of economic recovery, this can also indicate higher inflationary pressures especially if recession periods have passed for quite some time. This has been a source of objection from some emerging economies' governments particularly in QE2 when the maximum negative impact of the global crisis has appeared to pass, and the rise of prices is perceived as the build-up in inflationary pressures. Therefore, this finding supports the conclusion of some studies that QE episodes tend to cause capital inflows pressure to EMs, which then induce the increase in asset prices and credit activities, and put higher inflationary pressures in EMs (Borio, 2011; Barroso et al., 2015).

2.3.1.4 Industrial Production

As it is the case for other variables, the effect of US QE to industrial production for the emerging and the other advanced economies are not identical in the three QE periods, with the first QE having the largest positive impact compared to the other two QE episodes. Industrial productions in all groups of economies were severely impaired following the squeeze in US credit markets and drops in income due to the global financial crisis in 2007. The decline in industrial production is particularly severe in the advanced and US economies particularly in 2009 when the drop in industrial production was the worst for over ten years.

All groups of economies seem to have benefited from QE1 as the policy appears to have

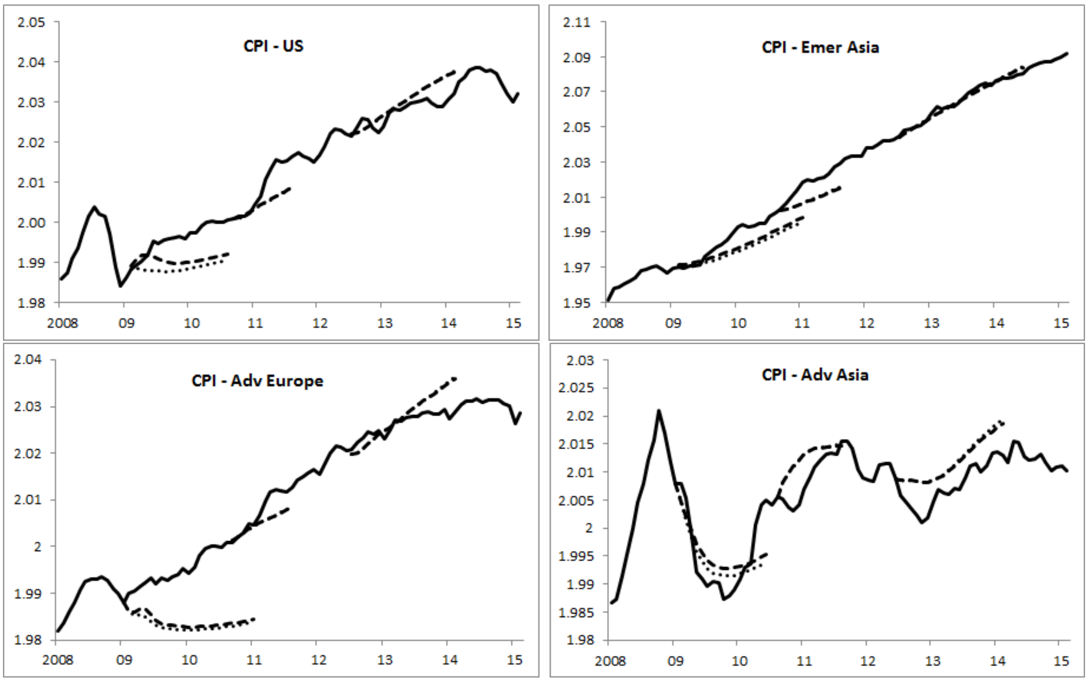


Figure 2.9: Conditional Forecasting - Price Indices

been successful in halting recessions period following the crisis as illustrated by the gradual rebound of their industrial production after the policy. In fact, emerging economies are able to return the level of industrial production back to its pre-crisis level only in 11 months period, unlike the advanced economies which until recently are still not able to return the industrial production to the pre-crisis level. This result suggests that the increase in import demand by the US economy to the emerging economies after QE1 may have had outweighed the loss in export competitiveness due to exchange rate appreciation pressures, suggesting that QE1 impact on EMs via the trade-flow channel is higher than the exchange rate channel.

2.3.2 The Impact of US QE on Interest Rates and Global Monetary Policymaking: Counterfactual Analyses

2.3.2.1 Long-Term Interest Rates

When the US Fed Funds policy rate becomes the zero lower bound after several stages of unconventional monetary policy accommodation, the Federal Reserve's target is shifted to reducing the long-term market rates through the buying of longer-term and riskier bonds. The inability to further decrease the short rates drove the Federal Reserve to influence credit creation and real economic activities by reducing the further end of market yield curves. Thus, as opposed

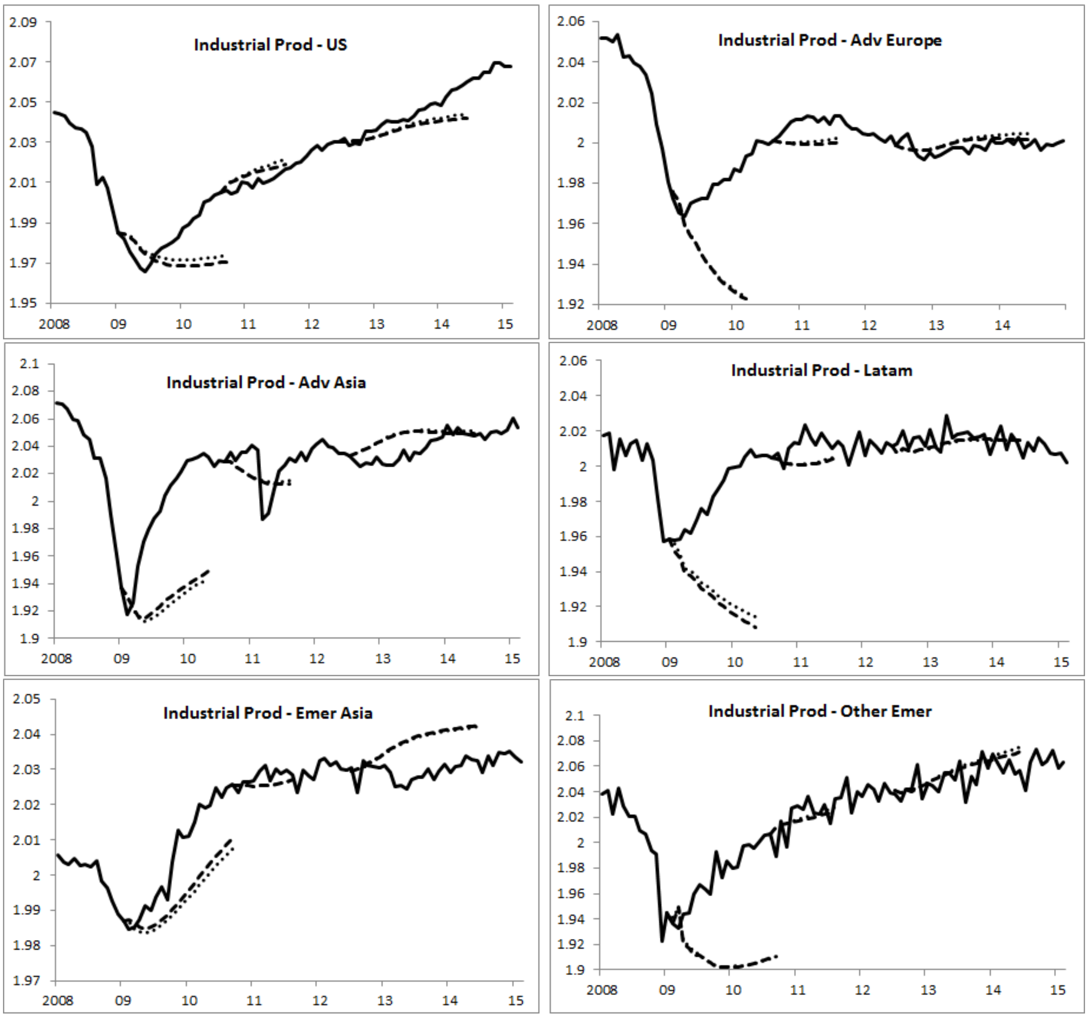


Figure 2.10: Conditional Forecasting - Industrial Production

to the usual monetary policy implementation where the short rates is the intermediate target, the term spread becomes the policy target during unconventional monetary policy execution.

In most emerging economies, short-term interest rates are still quite distant from the zero lower bound, thus monetary policy still works through the conventional domestic monetary policy transmission where monetary authorities attempt to influence the economy through short-term policy rates. However, the global long rates are also important for the level of long rates in emerging economies (Jain-Chandra and Unsal, 2012). Therefore, the spillover impact from US QE implementation on emerging economies' monetary policy and interest rates can materialize through either the short or long rates.

Our counterfactual analyses show that QE1 tends to decrease long-term interest rates in the US with a tendency to spread to other economies. In fact, the decrease in long rates appears to be quite sharp in the US and emerging Asia, and more gradual in advanced Europe and advanced Asia. In contrast, the implementation of QE2 and QE3 does not seem to produce the expected results. Counterfactual plots around QE2 suggest that in the absence of QE2 long-term rates are most likely lower than actual plots which means that QE2 is associated with higher long-term rates, which is counterintuitive. A closer look at the counterfactual analysis shows that long-term interest rates hikes is associated with QE announcement, whereas long-term interest rates decrease followed the actual Federal Reserve's real market operation which is started around January 2011. The same pattern as in the US long-term interest rates around QE2 is also observed in other groups of countries outside the US, suggesting the importance of US long-term interest rates in affecting domestic interest rates fluctuations in these economies. The impact of QE3 on long rates are counterintuitive particularly in the US itself, where QE3 does not lead to lower long-term rates, which also happens in emerging Asia. On the contrary, QE3 appears to reduce the long-term interest rates in advanced Europe and, to a smaller extent, in advanced Asia.

The results show the effectiveness of QE1 in reducing the long-term rates in the US economy as expected. The tendency of lower rates in the longer end of US yield curves and the reduction in global risks seem to spillovers to other economies including the emerging economies, in line with the finding by Jain-Chandra and Unsal (2012) that emerging markets long rates are influenced by foreign interest rates and global risks. In addition, this finding provides some support on the "portfolio-balance channel" of the US QE impact on emerging markets due to Lavigne et al. (2014). The reduced supply of US long-term securities following

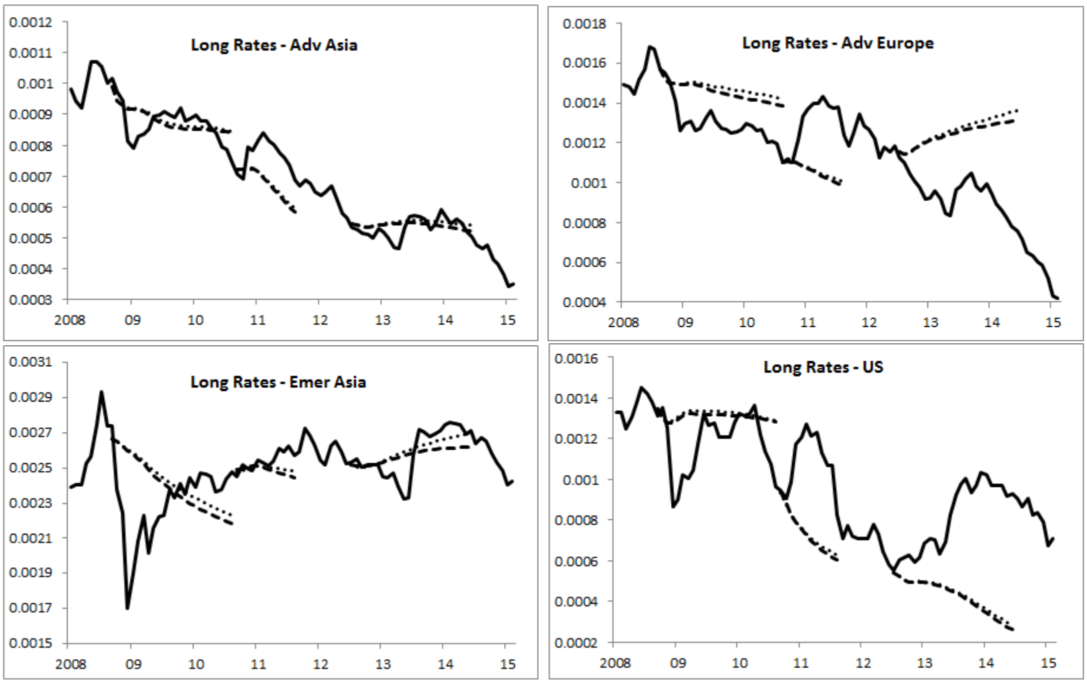


Figure 2.11: Conditional Forecasting - Long-term Interest Rates

the Federal Reserve open market operations lead investors to seek an alternative investment with the same maturity in emerging economies, and therefore increase demand and reduce the yield of long-term securities in the emerging economies.

The spillovers of global interest rates to domestic rates may complicate monetary policy conduct in these economies by weakening the connection between short-term policy rates and long rates/yields, especially when the domestic policy rule suggests a different direction of rates compared to the realized global long rates. For instance, domestic monetary authorities' stances in increasing the short policy rates may not necessarily translate into higher domestic long-term rates as expected, if global long rates are decreasing.

2.3.2.2 Short-term Interest Rates

Having bounded by the zero lower bound, the Federal Reserve continue with QE to reduce term and risk spreads. In a shadow interest rate setting where policy rates are allowed to go beyond zero, the Federal Reserve action is translated into further decreasing movement in the negative territory. Our study indicates quite a significant impact of QE1 on the reduction of short-term interest rates in the emerging and advanced economies. The results also show a tendency that the implementation of QE1 as monetary policy accommodation of the US economy is trailed by monetary policy accommodation everywhere else. The counterfactual analysis shows an otherwise higher level of short-term interest rates in all groups of economies in the absence of QE1, albeit to a lesser extent for Latin American countries.

Subsequent to the contagion of short rates reduction periods following QE1, there is a period where short-term interest rates in some economies seem to detach from the US monetary policy stance. In fact, starting from the third quarter of 2009 monetary policy stances in some groups of economies start to pick up, despite further accommodation in the US monetary policy. This movement is particularly noticeable in the emerging Asian economies and to some extent in advanced Europe and advanced Asia. This indicates that economic recovery is assumed around one year after QE1 outside the US economy and the inflationary pressures build up. This is what seems to drive monetary authorities outside the US to start increasing policy rates. This also explains why the effect of QE2 episode in the other economies' short rates are quite negligible, and even counterintuitive for emerging Asia because an otherwise lower short-term interest rates are likely to materialize in emerging Asia if QE2 is not implemented.

In contrast to QE2, QE3 affects foreign economies similarly to QE1 where the US monetary policy accommodation appears to have been followed by other economies, albeit with a lot lesser magnitude. Another important feature is the sharp increase in short-term interest rates in the emerging countries from June to October 2013 following the 'Fed talks' on QE tapering plan, which does not impact advanced economies short rates.

Our results provide evidence to our presumption following general cases of monetary policy contagion as highlighted by Gray (2013) and Hofmann and Bogdanova (2012). In particular, following QE1 there is a tendency for monetary policy contagion in the global economy led by the US economy. A series of accommodative monetary policy moves by the Federal Reserve in order to bolster domestic economic recovery tends to be trailed by monetary policy rates everywhere else. However, the linkage is not equally strong for every period and for every country. When QE2 is implemented, domestic inflationary pressures outside the US economy appears to be significant suggesting emerging markets' authorities to increase short rates. Thus, there are periods when cross-country short rates linkages are weakened, i.e. when domestic conditions like growth and inflation become more of a concern. In periods where the linkage between foreign and domestic policy rates is weaker, and thus interest rates differentials are widened, emerging economies policy implication is to implement capital flows management and macroprudential policies to help contain the risks from volatile capital flows.

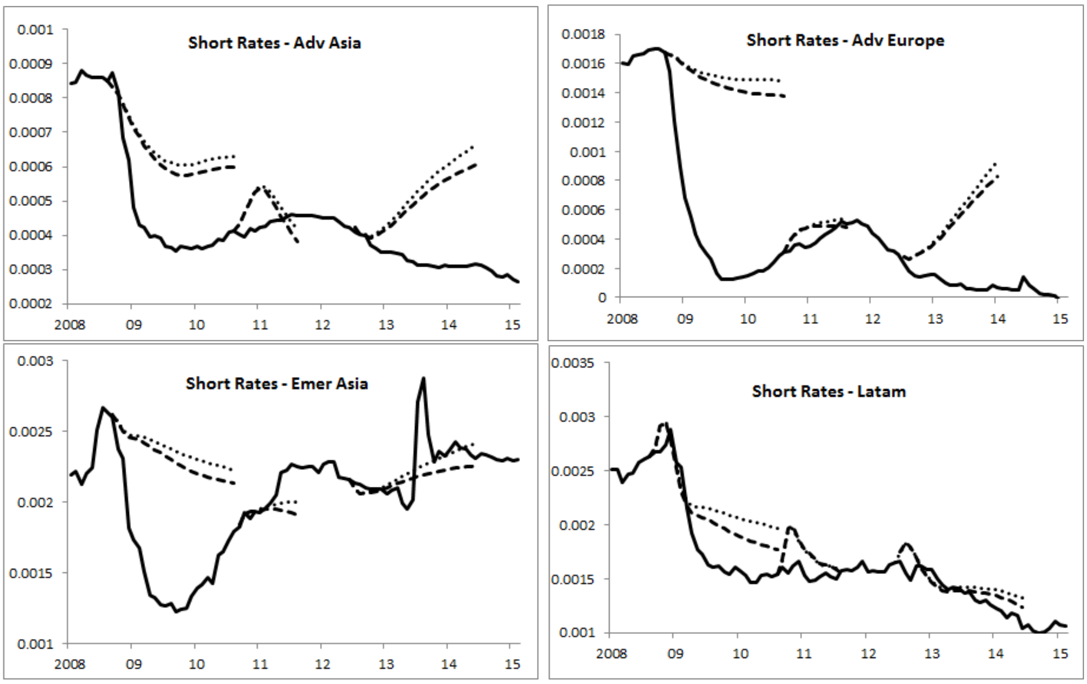


Figure 2.12: Conditional Forecasting - Short-term Interest Rates

2.3.3 Impulse Response Analyses

In order to study how global macroeconomic variables and monetary policy reacted to US monetary policy in a wider context that also includes non-QE periods, we study the impact of US monetary policy stance on macroeconomic variables in the US and other economies using full data from January 1995 to February 2015. We use the method of Generalized Impulse Response Functions (GIRFs) of Koop et al. (1996) and Pesaran and Shin (1998) to avoid the problem of having to determine the orderings of the variables according to the theory, which is particularly challenging in a multi-country setting. In order to analyse the impact of monetary policy accommodation, we impose one standard error of negative shock to US monetary policy variable. To put into perspective, the magnitude of one negative standard error shock to the US monetary policy variable in the impulse response analysis is approximately equivalent to a decrease of 28 bps of US policy rate (EFFR). The same size of the standard deviation of the US monetary policy variable is also equivalent to an increase of around USD 140 billion of the US Federal Reserve balance sheet size. We perform bootstrapping method with 2,000 bootstrap replications to produce the impulse response functions as well as the 90% bootstrap confidence intervals.

Our impulse response functions are available in individual countries and in region groupings. For simpler discussion, in the impulse response analysis part we group the countries into three classifications only, that is the US, advanced, and emerging economy groups. Figure 2.14, 2.15, and 2.16 show the impulse response functions of the US, advanced, and emerging economies as groups. Figure 2.17 and 2.18 show the range of maximum and minimum impact of impulse response function for each country in the groups.

The one negative standard error shock in the US monetary policy variable on impact has a small negative effect on risk appetite index but then becomes positive after 4 months, but then back to approximately normal level in around 6 months (Figure 2.13). In the long run, the effect of negative US monetary policy shock is to lower global risk appetite. This lower risk appetite poses risks of higher capital inflows pressures to non-US countries. There is significant decrease in the index of financial stock and oil prices by around 0.05 index to negative US monetary policy shock equivalent to a decrease of 28 bps of US policy rate or an increase of around USD 140 billion of the US Federal Reserve balance sheet size.

Responding to the same magnitude of negative US monetary policy shock, the exchange rate in both the advanced and emerging countries appreciates as shown in Figure 2.15 and 2.16, although the confidence interval for impulse response function in exchange market appreciation is quite large for both groups. The largest appreciation pressure impact is experienced by South Africa and Mexico for the emerging country group, and Japan and Australia for the advanced country group (Figure 2.17 and Figure 2.18).

A 28 bps US monetary policy accommodation shock affects the stock price with a decrease by 0.4% and 0.5% in the stock prices of the emerging and advanced economies, respectively, in one-year period after the shock, with China and Greece experiencing the lowest decrease compared to other countries in their respective group. In the long run, the pattern of GIRF on the stock prices following a negative standard error shock to US monetary policy rate is largely similar to industrial production. The effect of negative shock to US monetary policy is to decrease industrial production within the first 12 months period after the shock with a maximum impact of 0.4% and 0.5% negative change in the emerging and advanced groups, respectively. This relationship reflects the policy stance of the Federal Reserve and other central banks to reduce short-term interest rates during periods of low prices and slow economic activities, where in such situation monetary policy accommodation is expected to encourage real economic activity. After 12 months period, stock prices and industrial productions start to slightly pick up indicating that the expected effect of short-term policy rate reduction begins to materialize.

The effect of one standard error negative US monetary policy shock is to increase inflationary pressures in emerging economies group of around 0.03% change on impact, but a slightly lower inflationary pressure of around 0.02% change on impact in the advanced economies. For the advanced economies, the prevailing relationship between low interest rates and low prices seems to explain monetary authorities' effort to encourage real economic activities as suggested by monetary policy rule. In contrast to the advanced economies, the opposite relationship of low interests rate and higher prices in the emerging economies provides evidence that a lower US policy rate is likely to be problematic for emerging economies due to the higher inflation pressures following lower rates.

The negative one standard error in monetary policy shock on impact, equivalent to a 28 bps decrease or expansion in USD 140 billion, has 6 bps and 2 bps negative effects of long rates in the emerging and advanced economies, respectively. Similarly, the same shock is also more likely to reduce short-term rates by about 5 bps and 7 bps on impact for both the advanced and emerging country groups, respectively. It can be seen that the impact of the shock to the advanced economies' long rates is dominated by Greece.

The GIRFs of the short-term policy and long-term rates provide evidence of monetary policy contagion from the US economy to other economies across the globe. Monetary policy expansion in the US is more likely to be followed by lower short-term policy rates elsewhere in order to maintain domestic stability, decrease interest rate differentials, and reduce exchange market appreciation pressures. The long-term interest rates are also more likely to be contagious globally due to freer capital flows which allow higher interconnection between global markets. A decrease in the long-term yield in the advanced economies will likely induce investors to find alternative investments in emerging economies, thus increasing the demand for long-term bonds and decreasing long-term yields in these economies. Thus, this result supports our counterfactual analysis that US monetary policy tends to spread to other economies by influencing the formation of the short-term policy rate in other economies. Also, the long-term interest rates are interconnected across the globe. Therefore, when the US monetary policy aims to reduce the US long-term rates, it will be followed by lower long-term rates elsewhere, thus complicating the transmission mechanism of monetary policy in the non-US countries.

2.3.4 Generalized Forecast Error Variance Decomposition (GFEVD)

Figure 2.19 shows the GFEVD of the US monetary policy variation that are calculated to assess the importance of US domestic and global variables in the US monetary policy determination, and the number adds up to 100% in each month period. The first observation from the GFEVD result is that the relative contribution of the US domestic and global variables are significant for the US monetary policy determination, whereas the relative contribution of all non-US variables are very low. This is not surprising as by construction the US variables and the global variables are important for the US monetary policy variations.

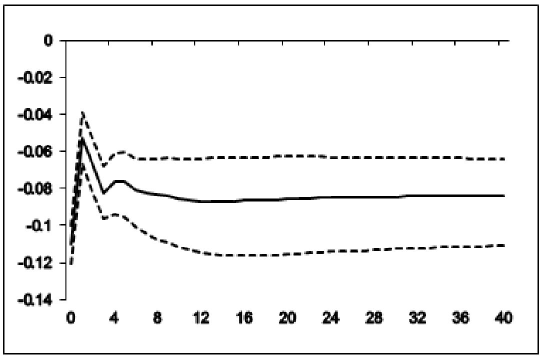
The second stand-out observation is that the US monetary policy is itself that mostly explains the forecast error variance decomposition of the historical shocks from 95% relative contribution on impact which then reduces to around 65% relative contribution after two years. This suggests that US monetary policy tends to have a strong auto-correlation component. The second most important contribution to explain forecast error variance decomposition of US monetary policy is the US industrial production with an average contribution of 6% throughout the two-year period. The next important variables determining US monetary policy are the global risk appetite variable, US stock price, the world financial oil index, and the US CPI with the relative contribution of around 3% for each variable throughout the two-year period.

2.4 Conclusion

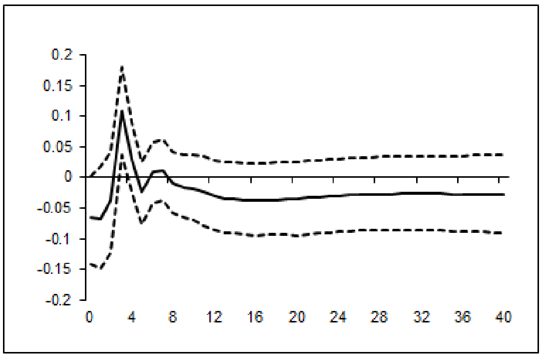
Our study aims at analyzing the macroeconomic and financial impact of US QE episodes on the domestic and global economy and how they affect global monetary policymaking. We find an asymmetric impact of QE episodes, with QE1 having the biggest impact on the US, the other advanced, and emerging economies macroeconomic variables compared to QE2 and QE3. We find evidence of large appreciation pressures in non-US countries following QE1 which may suggest the existence of massive influx of capital flows. QE1 appears to have been successful in halting recession periods following the global financial crisis in the global economy by increasing industrial production, stock prices, and price levels in all groups of economies. However, as the impact of QE1 begins to come into effect, inflationary pressures seem to increase particularly in the emerging economies.

The counterfactual analyses and GIRFs show some evidence of monetary policy contagion from the US to other economies across the globe that materialize through either the long or short rates. The results show the effectiveness of QE1 in reducing the long-term rates in the US economy as expected. The tendency of lower rates in the longer end of US yield curves and the reduction in global risks seem to spillovers to other economies. This finding provides some support for the "portfolio-balance channel" that the reduced supply of US long-term securities lead investors to seek alternative investment in emerging economies, and therefore increase demand and reduce the yield of long-term securities in other economies.

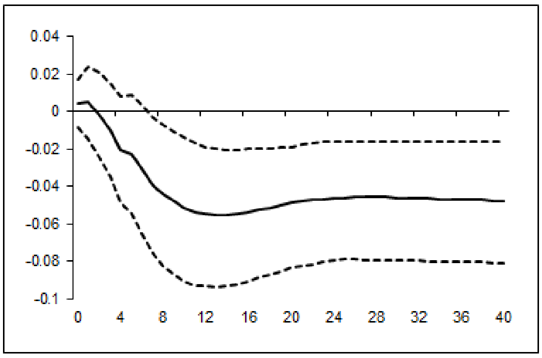
There is also a tendency of monetary policy contagion through the short rates as accommodative monetary policy moves by the Federal Reserve tends to be trailed by lower monetary policy rates everywhere else. However, the generalized forecast error variance decomposition shows that, on impact the variables that contribute mostly to the variance of US monetary policy shock are US domestic and global variables. Whereas the relative contribution of every single foreign economy variables to US monetary policy determination is less than 1% each.



(a) US Monetary Policy



(b) Risk Appetite



(c) World Financial and Oil

Figure 2.13: GIRF of one standard error negative shock to US monetary policy variable on risk appetite and world financial oil variable (in index unit)

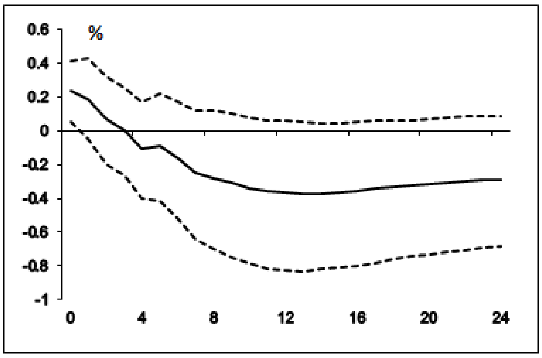
Table 2.1: The order of integration

	IP	PI	STR	LTR	SP	EMPI
Australia	1	1	1	1	1	0
Austria	1	1	1	1	1	1
Belgium	1	1	1	1	1	1
Brazil	1	1	-	-	1	0
Canada	1	0	0	1	1	1
Chile	1	1	1	1	1	0
Hongkong	1	1	1	1	1	-
China	1	1	-	-	1	0
France	1	1	1	1	1	0
Germany	0	0	1	1	1	1
Greece	1	1	1	1	1	1
India	1	1	1	1	1	0
Indonesia	1	1	0	-	1	0
Italy	1	1	1	1	1	-
Japan	0	1	1	1	1	1
South Korea	1	1	1	1	1	0
Malaysia	1	0	1	1	1	0
Mexico	1	2	0	-	1	1
Netherland	1	1	1	1	1	0
Phillippines	1	1	0	-	1	0
Singapore	0	1	1	1	1	1
South Africa	1	1	1	1	1	0
Spain	1	1	1	1	1	0
Sweden	1	1	0	1	1	0
Switzerland	-	1	1	1	1	0
Thailand	-	1	1	-	1	0
Turkey	1	2	-	-	1	0
UK	1	1	1	1	1	0
USA	1	1	1	0	1	-
Total I(1) or I(2)	24	26	21	21	29	8
Total variables	27	29	26	22	29	26

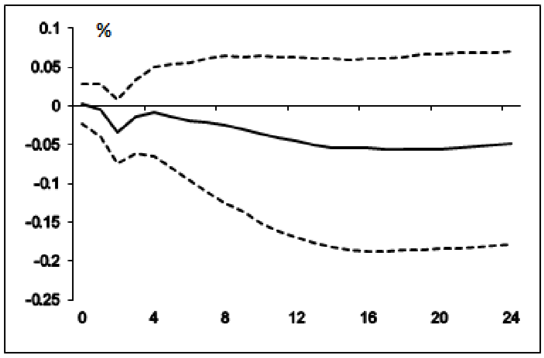
Note: IP = industrial production; PI = price index; STR = short term rate; LTR = long term rate; SP = stock price; EMPI = exchange market pressure; 0 = I(0); 1 = I(1); 2 = I(2); - = data is unavailable.

Table 2.2: Series from McCracken and Ng (2014) for the US monetary policy measurement

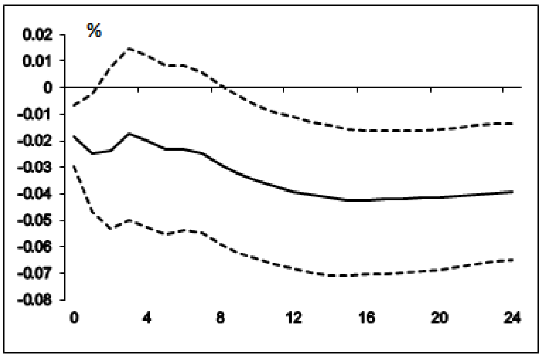
Classification	Code	Description
US Monetary Base	M1SL	M1 Money Stock
	M2SL	M2 Money Stock
	M2REAL	Real M2 Money Stock
	AMBSL	St. Louis Adjusted Monetary Base
	TOTRESNS	Total Reserves
	NONBORRES	Nonborrowed Reserves
	MZMSL	MZM Money Stock
US Policy Rates, T-Bills & Bond Yields	FEDFUNDS	Effective Federal Funds Rate
	TB3MS	3-Month T-bill
	TB6MS	6-Month T-bill
	GS1	1-Year T-bond
	GS5	5-Year T-bond
	GS10	10-Year T-bond
	AAA	Aaa Corporate Bond Yield
	BAA	Baa Corporate Bond Yield
Spreads	COMPAPFFx	CP – FFR spread
	TB3SMFFM	3 Mo. – FFR spread
	TB6SMFFM	6 Mo. – FFR spread
	T1YFFM	1 yr. – FFR spread
	T5YFFM	5 yr. – FFR spread
	T10YFFM	10 yr. – FFR spread
	AAAFFM	Aaa – FFR spread
	BAAFFM	Baa – FFR spread



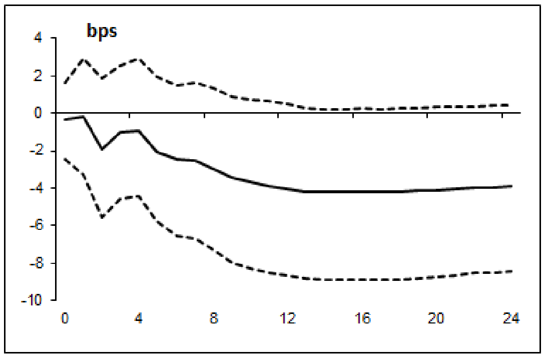
(a) Stock Price



(b) Industrial Production

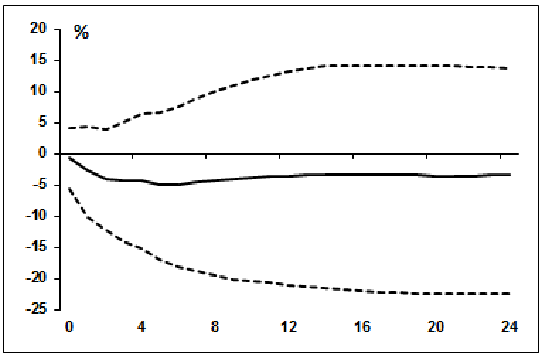


(c) Price Index

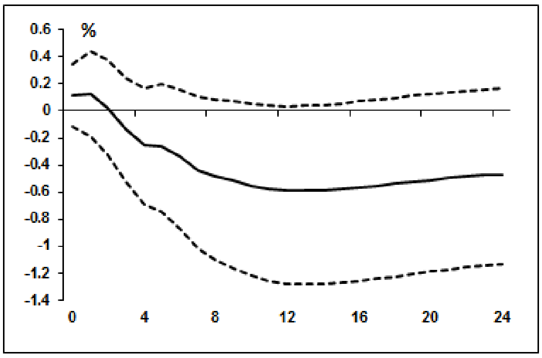


(d) Long Rates

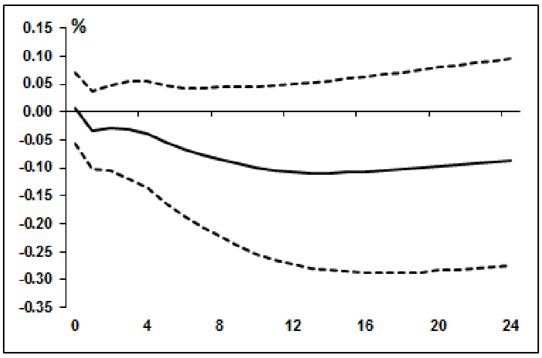
Figure 2.14: GIRF of 1 SE negative shock to US monetary policy on US domestic variables



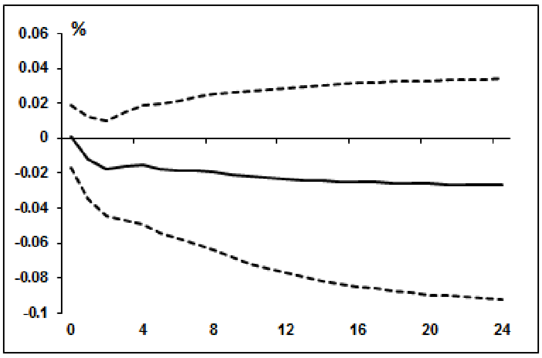
(a) EMP



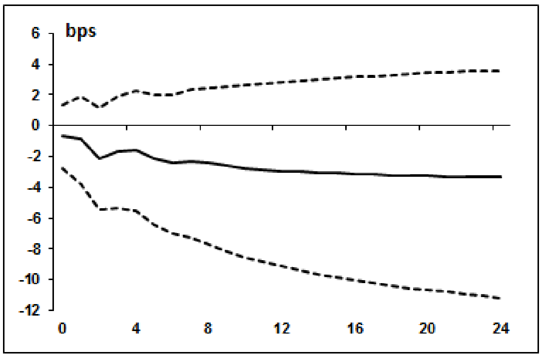
(b) Stock Price



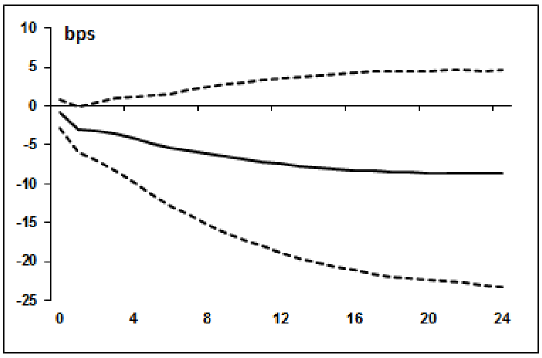
(c) Industrial Production



(d) Price Index

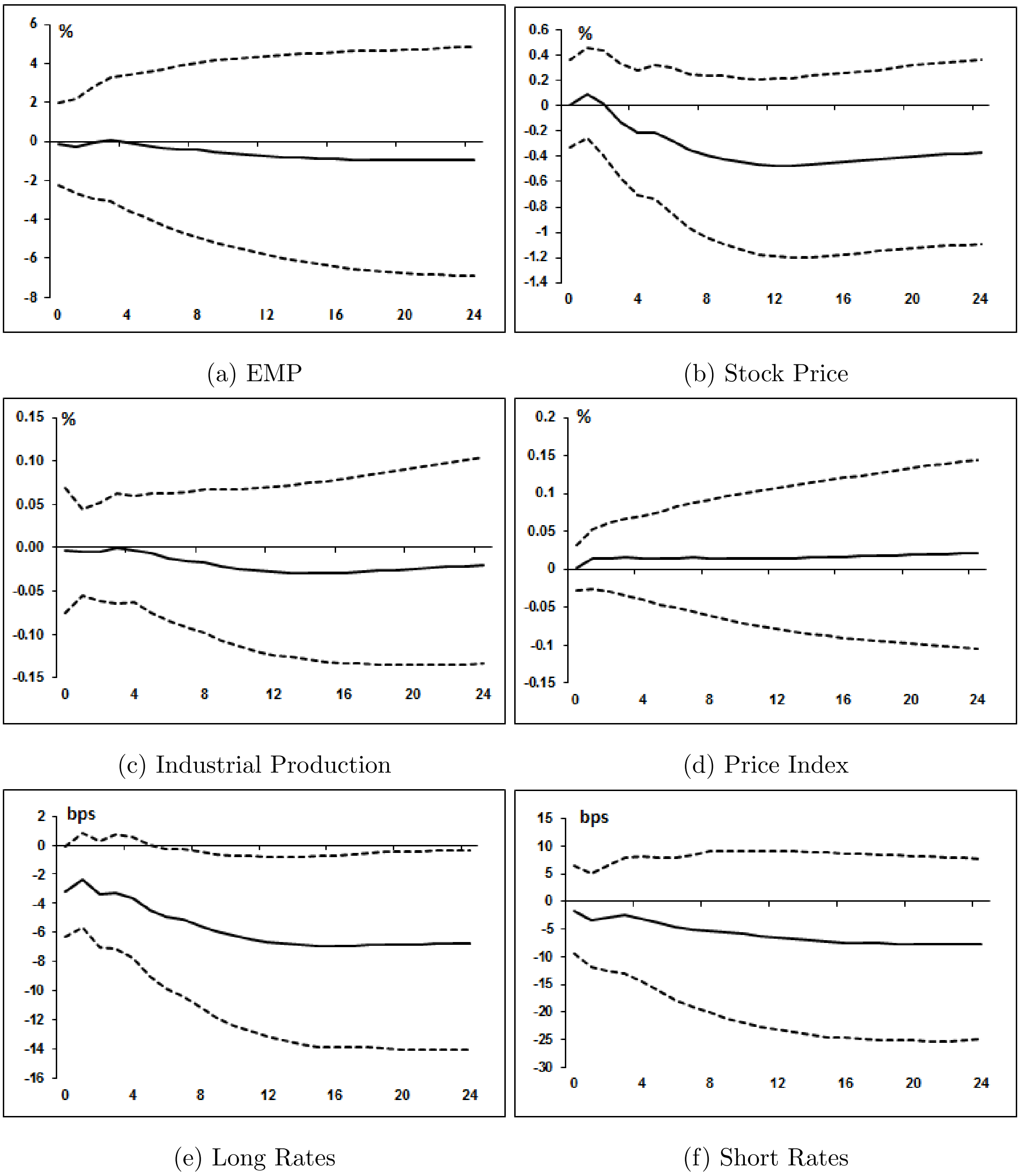


(e) Long Rates



(f) Short Rates

Figure 2.15: GIRF of 1 SE negative shock to US monetary policy on all advanced economies variables

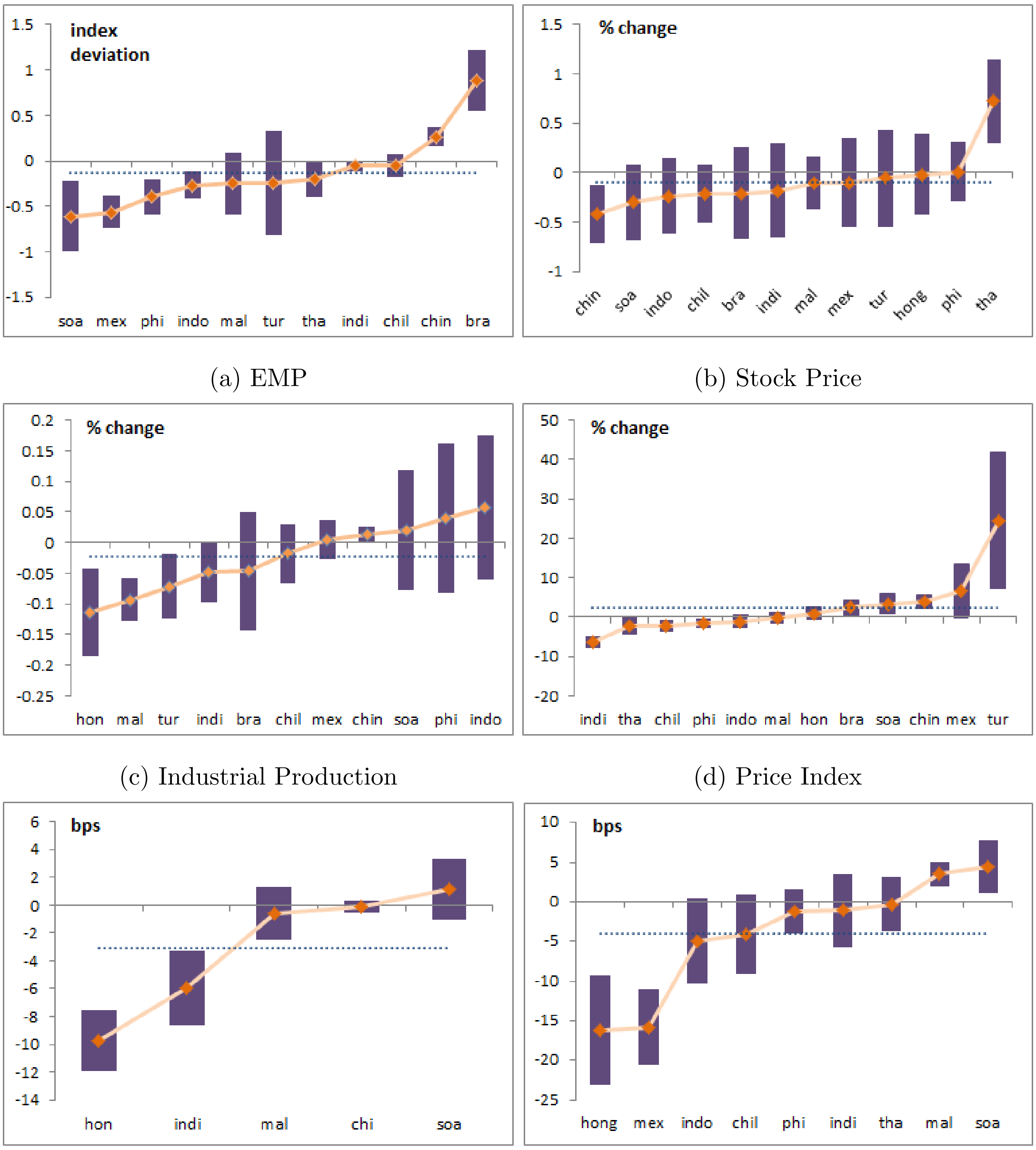


(a) EMP (b) Stock Price

(c) Industrial Production (d) Price Index

(e) Long Rates (f) Short Rates

Figure 2.16: GIRF of 1 SE negative shock to US monetary policy on all emerging economies variables



(a) EMP

(b) Stock Price

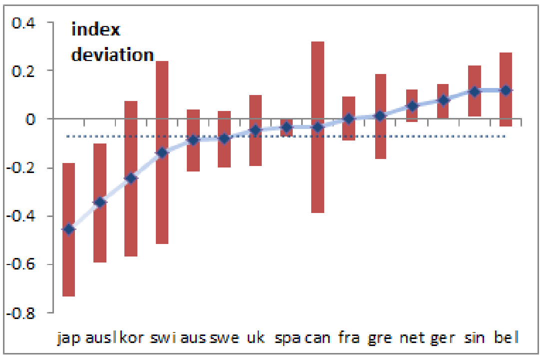
(c) Industrial Production

(d) Price Index

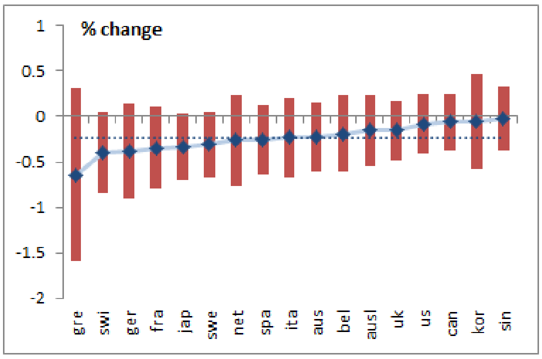
(e) Long Rates

(f) Short Rates

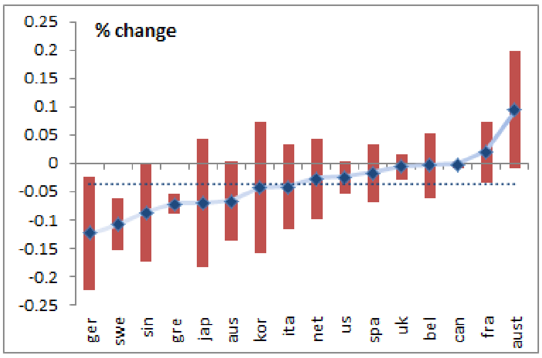
Figure 2.17: Range of impact of 1 SE negative shock to US monetary policy on all individual emerging economies variables



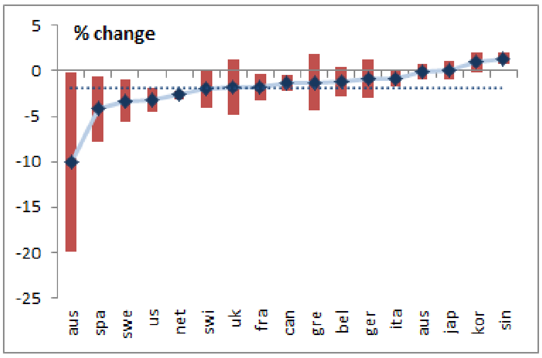
(a) EMP



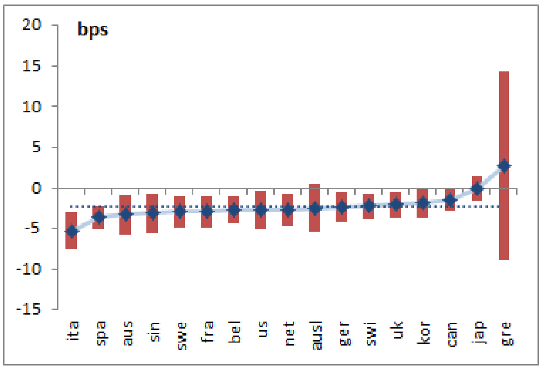
(b) Stock Price



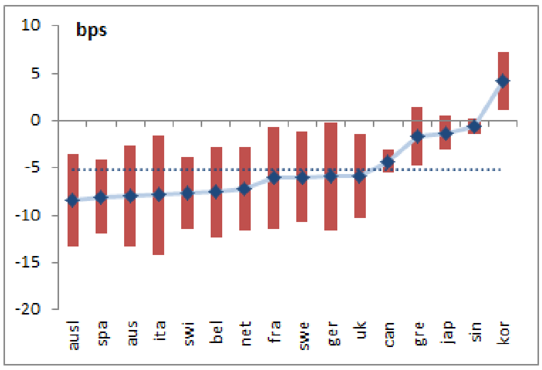
(c) Industrial Production



(d) Price Index

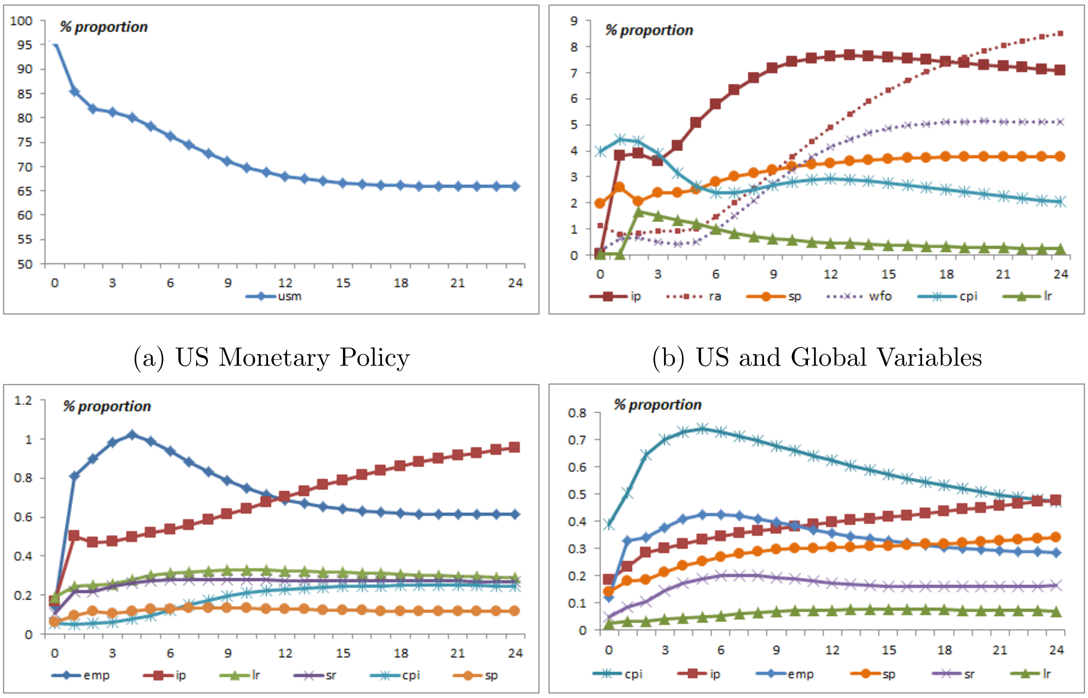


(e) Long Rates



(f) Short Rates

Figure 2.18: Range of impact of 1 SE negative shock to US monetary policy on all individual advanced economies variables



(a) US Monetary Policy

(b) US and Global Variables

(c) Advanced Economy Variables

(d) Emerging Economy Variables

Figure 2.19: Generalized forecast error-variance decompositions: a negative standrad-error unit shock to US monetary policy variable

Note: ip = industrial production; cpi = price index; sr = short term rate; lr = long term rate; sp = stock price; emp = exchange market pressure

Chapter 3

International Monetary Policy Spillovers to Emerging Economies

3.1 Introduction

Financial liberalization and globalization have brought opportunities for emerging economies to advance their national development by broadening the scope of financing resources. Apart from this positive impact, financial liberalization and globalization also come with great challenges to emerging economies as they face greater exposure to external financial shocks that may jeopardize domestic financial stability. The openness to international financial markets also triggers cross-border *policy* spillovers from the advanced to emerging countries. The implementation of unconventional monetary policy by the US Federal Reserve is a notable example of how the policy stance of a center economy, whose currency is the key reserve currency in the world, may affect monetary conditions in the rest of the world, and thus their monetary policymaking.

Following the US credit markets failure in 2007, the Federal Reserve swiftly responded through conventional monetary policy by means of interest rate reduction, which were then followed by the unconventional measures in the form of large-scale asset purchases program as the policy rate hit the zero lower bound (Figure 3.1). The policies were implemented to reduce the strain in the credit market by minimizing risk and term premium of long-term bonds to encourage financial markets to restore its function as a liquidity provider in private credit markets. Although the objective of the policy was largely domestic, international financial market integration allows the impact of any policy implementation in a centre economy to spillover across borders. In particular, the first episode of unconventional monetary policy (QE1) which was started in late November 2008 appears to not only able to avoid the US economy from further recession, but also to improve the global economic condition.

Figure 3.2 presents the macroeconomic and financial conditions of emerging and developing economies, calculated by the International Monetary Fund (IMF). The positive effect of QE1 appears to have helped the global economy recover from the crisis, which started to materialize in emerging economies around one year after implementation. This can be seen by an increase in export and import activities, and the slowing down of inflation, which led to GDP recovery.

Following QE1, the Federal Reserve introduced QE2, which began in November 2010, followed by QE3 in June 2012. As opposed to the outcomes after the first episode of quantitative easing, the next two rounds of quantitative easing did not seem to impact the developing and emerging economies positively. Earlier studies argue that the extended periods of monetary policy easing has resulted in an increase of capital inflows in most of emerging economies, particularly Latin America and Asia (Borio, 2011; Chen et al., 2012b; Barroso et al., 2015; Ahmed and Zlate, 2014; Sahay et al., 2014).

Unlike capital inflows in the form of foreign direct investment, capital inflows in the form of short-term portfolio investment are less preferable because of its destabilizing features. An increase in capital inflows to emerging economies induces domestic exchange rates appreciation. If the emerging economy implements a fully flexible exchange rate regime, the destabilizing capital inflows will eventually recede as domestic currency appreciation makes the investment in emerging countries more expensive. Also, because domestic appreciation damages export competitiveness, most emerging economies may want to intervene in their foreign exchange market to keep the exchange rate largely stable. As a result, the destabilizing capital inflows continue and the foreign reserves enlarge. In order to discourage more destabilizing capital inflows, the monetary authority of an emerging country may decide to reduce policy rate, thus decreasing the interest rate differential with the centre economy. This suggests that if the domestic financial market is open, then the large monetary policy easing of advanced major economies may instigate loose monetary policy stances everywhere else, particularly in the emerging economies, thus generating a sequence of monetary policy contagion effect across the world. Previous works like Gray (2013), Taylor (2013), and Hofmann and Bogdanova (2012) study the contagion in monetary policy stance. They find that monetary policy contagion is in

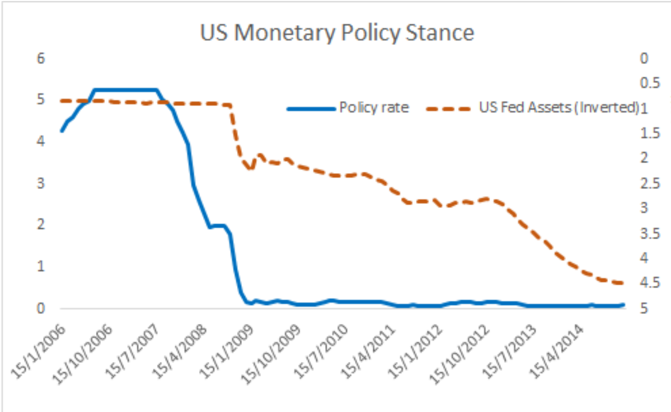


Figure 3.1: US monetary policy stance, blue line: US federal fund rate, orange dashed line: US Federal Reserve total asset (in inverted plot), Source: Datastream.

fact not a new phenomenon as there is a tendency for monetary policy stances of the countries to follow each other going back at least to the last two decades (Figure 3.3).

Against this background, this paper investigates the challenges faced by emerging countries arising from monetary policy decisions of the centre economy by utilizing a small open economy model in a Dynamic Stochastic General Equilibrium (DSGE) framework with financial friction *a la* Bernanke et al. (1999). In particular, it aims to trace the responses of a typical emerging country during the periods of large US monetary policy easing in the aftermath of the great financial crisis in 2007-8. First, it studies the implication of monetary policy relaxation in the centre economy on the macroeconomic and financial stability of the emerging economy. It then discusses how common features of a typical small open emerging economy, such as financial friction and liability dollarization, may exacerbate the impact of foreign policy shock on the domestic economy. Subsequently, this paper analyses the implication of a monetary easing response by the small economy following the foreign rate shock as observed particularly following the first round of QE (as shown in the second graph of Figure 3.3). The aim of this exercise is to study the implications of contagion for the emerging economy.

Although some studies have attempted to analyse the impact of the US QE on the global economy in a DSGE framework (see, for example, Haberis and Lipinska (2012) and Alpanda and Kabaca (2015)), these studies fail to consider the implications of US QE on monetary policymaking particularly in the emerging economies: something we find empirically significant in the second chapter. This finding and the analyses on the policy response by the emerging economies have important policy implications. First, if the implementation of monetary policy by a centre economy alters monetary policymaking in the other economy, even after adopting

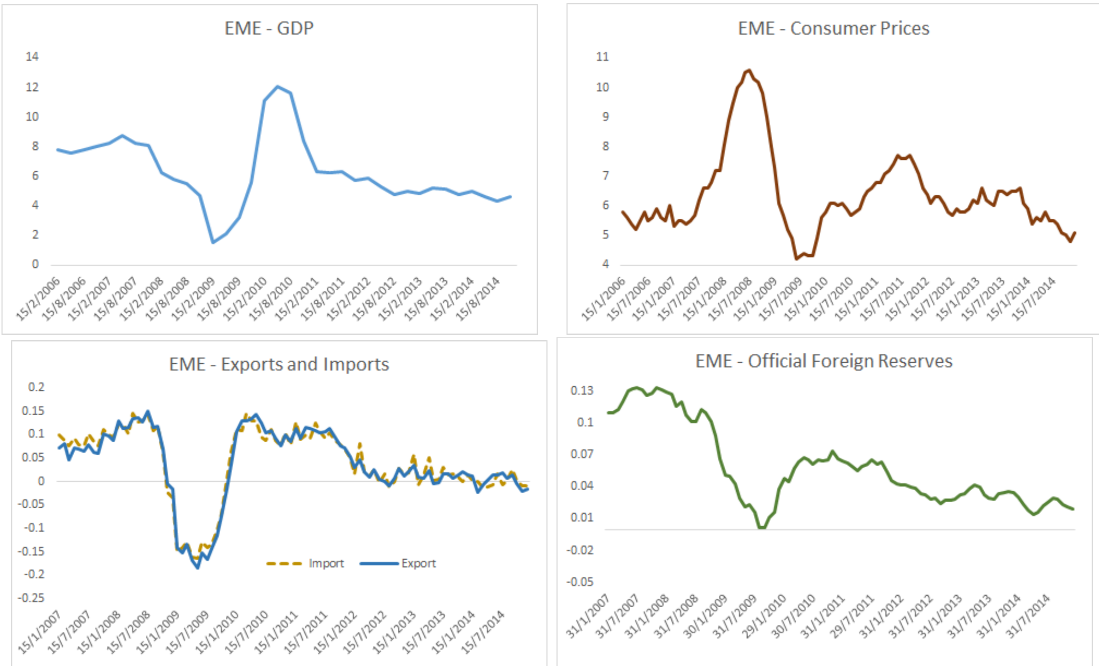


Figure 3.2: Emerging and developing economies aggregated data, aggregation calculated by the IMF.

Note: GDP is in percentage change year-on-year; Consumer prices are for all items in percentage change year-on-year; The values of export and import is first differenced of the log of export and import values in USD; The official foreign reserve assets is first differenced of the log of foreign reserve value in USD. Source: Datastream.

a flexible exchange rate regime, then monetary policy in periphery economies may not be as independent as suggested by standard open economy macroeconomic theories. Second, if the cross-border monetary policy spillovers from the core country exist and are significant, then monetary policymakers should increasingly become aware of the global dimension of their tasks, and thus need to internalize each others' economic condition and policy stances in policymaking as suggested by Borio (2011) and Caruana (2012). This chapter attempts to address these omissions. In particular, we utilize a DSGE framework to trace out how this policy contagion materializes to understand the reason behind the policy stance pursued by emerging economies, and then discuss the ramifications of such policy stance.

In order to study the challenges faced by a small open emerging economy, a DSGE framework is chosen because it allows us to analyse the possible impact of current economic choices on the future outcome of all macroeconomic and financial variables in the system. The model also allows us to include different economic players, e.g. consumers, firms, and entrepreneurs, and to study how their aggregate behaviour affects macroeconomic variables. Certain characteristics that we would like to include in the model are embedded in model specification and the choice of parameter values. For instance, the inclusion of financial friction in the model is aimed at studying the impact of financial market imperfection on domestic financial stability, in particular, whether the financial market imperfection amplifies the impact of external shocks on the financial condition of an emerging economy.

For calibration and parameter values, the model has characteristics that resemble a typical emerging Asian country, in particular Indonesia. Although the specific characteristics of Asian emerging countries are quite diverse, these countries share a similar economic environment and often face the same set of challenges in maintaining domestic financial stability. During the period of 1997-8 Asian financial crisis, these countries experienced a foreign credit mismatch problem that led to currency devaluations and a drop in foreign investor confidence, which then brought about massive capital reversals. As a result, these economies underwent a period of economic recession and financial restructuring. A decade following the Asian financial crisis, these economies experienced the impact of the global financial crisis that was originated externally. The 2007-8 global financial crisis shows how damaging external shocks can become to financial stability in an open emerging economy. Despite the relatively benign conditions in emerging economies prior to the global crisis, the crisis that was originated in the credit market failures of the advanced economies was capable of producing recessions in many emerging economies.

Asian emerging countries possess several characteristics that are typical of a small open economy. The economy is "small" in the sense that it can be affected by the rest of the world, but not *vice versa*. It is "open" in the sense that it embeds households that involve in international risk-sharing activity through international bond holdings and firms that borrow foreign currency debt to fund their investment activities. The economy also has firms that produce export products for the rest of the world. This makes the country dependent on global demand on its export and the price of its exported products in international markets. Also, the fluctuation of its domestic exchange rate against major reserve currencies adds more risks to export goods competitiveness, and thus affects internal macroeconomic stability. In general, these openness features of the emerging economy increase its exposure to external financial conditions.

The small open economy has a large number of entrepreneurs who borrow externally in order to finance their investment projects. The high volume of foreign currency denominated borrowing is typical of emerging market economies, i.e. "liability dollarization" problem, exposing the country to risks related to exchange rate fluctuations and shifts in investors' confidence.

In addition to liability dollarization, the domestic financial market in this economy also exhibits financial market imperfections. Financial market imperfections take the form of imperfect information in credit market via the inability of investors to examine the results of investments performed by borrowers. In order to cover the risks of asymmetric information, there is an external risk premium which raises the costs of obtaining funds externally above costs from raising funds internally. This external finance premium is linked to the leverage ratio and the net worth (i.e. collateral) of the borrowers. During unfavourable financial conditions, where the leverage ratio is high and net worth is low, the external finance premium increases, which then leads to a higher probability of default by firms. Gertler (1988) argues that financial market conditions and fluctuations are not simply passive reflections of the business cycle, but are in themselves major factors contributing to the severity of booms and busts in economic activity. Similarly, Bernanke et al. (1999) show that the existence of financial friction can significantly amplify the effect of shocks.

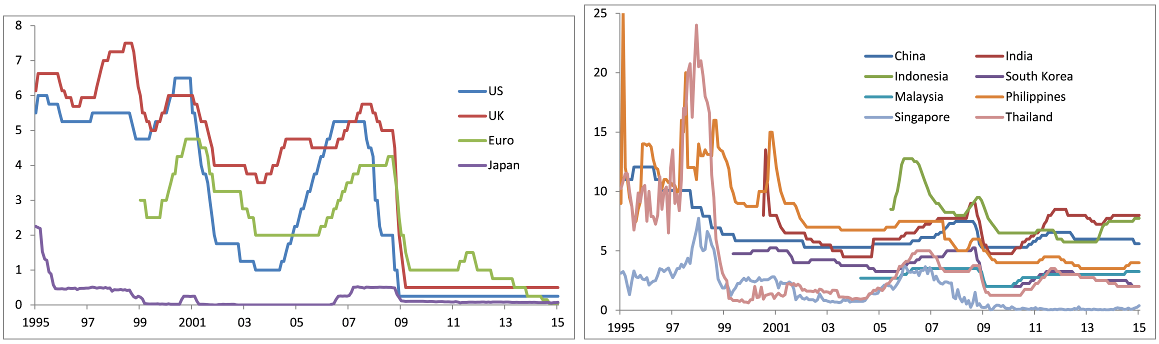


Figure 3.3: Monetary policy rates, source: Datastream

3.2 Literature Review

In a frictionless capital market, the financial structures of firms do not influence their investment decision and the cost of acquiring internal funds is the same as external funds. If there is an information asymmetry between the lenders and borrowers however, the lenders are unable to observe the outcome of investment decisions and so will require higher returns on lending or a high level of collateral to support the lending. As a result, the financial structures of borrowing firms, such as net worth, will determine their investment decision. Furthermore, in order to cover the risks arising from informational asymmetries, external financing becomes more expensive forming a wedge between the external and internal cost of finance.

The implication of financial market friction is that, a relatively small shock in the financial markets can exert a persistent and amplified impact on the real economy. Also, the implication of this mechanism for policymaking is that the credit market channel of the monetary policy transmission mechanism may be undermined by the presence of financial market friction.

Because of the potential importance of credit market frictions in explaining the behaviour of real macroeconomic data, many studies, especially those using the DSGE framework, have built credit market friction mechanism into DSGE models such as (Kiyotaki and Moore, 1997; Carlstrom and Fuerst, 1997; Bernanke et al., 1999). These models can be distinguished by the different ways financial friction is introduced.

Among the earliest work on financial friction is Kiyotaki and Moore (1997). The study is a theoretical work that is intended to explain the transmission mechanism of an endogenous development in credit limits which interacts with asset prices. The problem arises from the inability of lenders to force borrowers to pay their debts unless the debts are secured by certain assets. Thus, the credit limit of borrowers is affected by the price of the assets owned by borrowers. At the same time, the asset prices are affected by the credit limits. Kiyotaki and Moore (1997) show that the dynamic relationship between credit limits and asset prices generates a transmission mechanism that makes shocks persist, amplify, and spread.

Another early work on credit market imperfection is Carlstrom and Fuerst (1997), which focuses on the presence of agency costs to explain the hump-shaped aggregate output behaviour. Following a shock to productivity, the return from internal funds increases, which reduces agency costs gradually. Households delay investment decisions to wait until agency cost is at its lowest, which creates the hump-shaped aggregate output and net worth as observed in empirical data.

Although both studies work on financial friction, the difference between the two earlier financial friction studies is that, in Kiyotaki and Moore (1997) borrowing is so tightly linked to the net worth level that default does not exist in equilibrium, while in Carlstrom and Fuerst (1997) lending exceeds net worth, therefore, a default is an equilibrium phenomenon.

Another paper introducing financial friction is Bernanke et al. (1999) (BGG). Similar to Kiyotaki and Moore (1997), Bernanke et al. (1999) explore the role of credit market frictions on business cycle fluctuations. The key mechanism of the BGG model is the existence of a direct linkage between the external finance premium and the net worth of potential borrowers. This study also introduces money and price stickiness into the model to study how credit market frictions affect the monetary policy transmission mechanism. They show that the financial friction is significant in explaining business cycle dynamics.

Gertler et al. (2007) continue the work of previous studies on financial friction with an emphasis on an emerging economy context, especially to mimic the behaviour of the Korean economy during the financial crisis in 1997-8. They conclude that the existence of financial frictions is significant, explaining around half of the downturn in overall economic activity. They also perform a counterfactual analysis on the impact of a fixed exchange rate regime and conclude that fixing exchange rates will more likely cause a substantially higher welfare losses following a financial crisis than under a flexible exchange rate regime.

As with Gertler et al. (2007), Devereux et al. (2006) extend earlier works in an open emerging economies context, stressing the balance-sheet related financial friction. Using this balance-sheet related friction, they examine the response to shocks to world interest rates and the terms of trade, and compare the results under alternative monetary rules. In addition, they also compare the impact of different speeds of exchange rate pass-through on the response of real variables.

Ozkan and Unsal (2017) include the financial friction into a two-country DSGE model in order to examine the transmission of the global financial crisis from advanced countries with financial friction into emerging market countries. They find that the effectiveness of monetary policy is determined by the degree of financial contagion, the degree of trade openness, and the scale of foreign currency denominated debt in emerging economies.

Merola (2010)'s work is built on Gertler et al. (2007) and Devereux et al. (2006) which adds two features of emerging economies. First, she extends the model to a two-sector economy: a non-tradable and a tradable sector. This allows different price staggering mechanisms to influence the model. While the non-tradable sector firms are monopolistic competitors, which can set their optimal price, tradable sector firms are the price taker in the export sector. The second feature is liability dollarization which adds vulnerability of emerging economies to external shocks.

Harmanta et al. (2014) build a banking sector DSGE model for the Indonesian economy with financial accelerator mechanism that is extended from Gerali et al. (2010) and Christiano et al. (2005). The aims of this study are to explore alternative policies in order to mitigate shocks from banking sectors. The core framework of this paper is different to ours, however we refer to some of their parameter values for the Indonesian economy for our calibration purpose.

Despite that many DSGE studies have adopted financial friction mechanisms into DSGE frameworks, it is also worth mentioning that there are some studies that do not find much support for financial friction mechanisms such as (Christensen and Dib, 2008; Gelain et al., 2009; Brzoza-Brzezina and Kolasa, 2013). Christensen and Dib (2008) finds that the presence of the financial accelerator amplifies and propagates the effects of demand shocks on investment, but the importance of the financial accelerator for output fluctuations is relatively minor. Gelain et al. (2009) concludes that theoretical financial accelerator model are not supported by the data, whereas Brzoza-Brzezina and Kolasa (2013) concludes that BGG model does not make a clear improvement over the New Keynesian benchmark in terms of marginal likelihood and similarity of impulse responses to those obtained from a Vector Auto-Regression model.

Our paper is closest to Devereux et al. (2006) and Merola (2010) in terms of the model framework. While Devereux et al. (2006) focus mainly on the degree of exchange rate pass-through and the implications for the ranking of monetary rules, this paper focuses on discussing the implication of foreign monetary policy stance on domestic stability. Our paper is distinct from Merola (2010) as our analysis focuses on foreign shocks, whereas Merola (2010) focuses on domestic shocks. This paper also differs from Devereux et al. (2006) and Merola (2010) with regard to calibration of the parameters. Where possible, we use Indonesian data to determine the parameters and steady state values, for instance, in order to determine the relative size of the non-traded and export sectors. When Indonesian data are not available, we use the parameter or steady state values of other emerging Asian economies.

3.3 Model Presentation

The core framework of this study is an open economy model with a financial friction along the lines of Bernanke et al. (1999), Devereux et al. (2006), Merola (2010) and Ozkan and Unsal (2017). The financial friction links the condition of a borrower's balance sheet to capital demand. This mechanism allows asset prices to affect the borrower's balance sheet and magnifies the effect of the external shock to the domestic economy.

The structure is a standard two-sector small open economy model. Two goods are produced, a domestic non-traded good and an export good, the price of which is fixed on world markets. Within the model there exist four domestic agents, households, firms, entrepreneurs, and the monetary authority. The households work, save, and consume non-tradable and imported tradable goods. In addition, there exists "rest of the world" sector where the export product is consumed, foreign-currency prices of export and import goods are set, and lending rates are determined.

Firms in both sectors hire labour from consumers-households and rent capital from entrepreneurs to produce goods which are consumed by domestic households and foreign importers. Firms in the non-traded sector face monopolistic competition, therefore they set prices in a staggered way. We assume Rotemberg (1982) price-setting mechanism where firms face a small direct cost of price adjustment. This way we introduce nominal rigidities that allow for monetary policy effect. Entrepreneurs borrow from foreign lenders under contracts for investment financing. The monetary authority sets interest rates according to an interest rate rule.

3.3.1 Households

There is a continuum of consumers/households of measure one which is infinitely-lived and seeks to maximize:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \eta \frac{H_t^{1+\psi}}{1+\psi} \right), \tag{3.1}$$

where C_t is a composite consumption index, H_t is labour supply, E_t is the mathematical expectation conditional upon information available at t, β is the representative consumer's subjective discount factor where $0 < \beta < 1$, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, ψ is the elasticity of labour supply, and η is just the coefficient of labour in utility.

Households consume a composite good which consists of non-traded and imported goods according to a constant elasticity of substitution (CES) function as follows:

$$C_t = (a^{\frac{1}{\rho}} C_{Nt}^{\frac{\rho-1}{\rho}} + (1-a)^{\frac{1}{\rho}} C_M t^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}, \tag{3.2}$$

where $\rho > 0$ is the elasticity of substitution between the consumption for non-traded goods and import goods, a is the share of non-traded goods price in the price index, C_{Nt} is the consumption of non-tradable goods and C_{Mt} is the consumption of imported goods.

Similarly, the price index is a composite of non-traded and imported goods prices also using the CES function:

$$P_t = (a P_{Nt}^{1-\rho} + (1-a) P_M t^{1-\rho})^{\frac{1}{1-\rho}}, \tag{3.3}$$

where P_{Nt} is the price of non-tradable goods and P_{Mt} is the price of import sector goods.

Households consumption for both the non-traded and imported goods is differentiated across a continuum of goods i which for non-traded goods it is $C_{Nt} = \left[\int_0^1 C_{Nt}(i)^{\frac{\lambda-1}{\lambda}} \mathrm{d}i \right]^{\frac{\lambda}{\lambda-1}}$, where λ is the elasticity of substitution across varieties of goods.

The households borrows foreign-currency external debt D_t which is subject to small portfolio adjustment cost $P_t \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2$, where $\bar{D}$ is an exogenous steady state level of net foreign debt, at a given interest rates i_t^*. The households can also borrow in the domestic denominated bond market B_t at an interest rates i_t, without investment adjustment costs. Thus, the households' revenue flow comes from the wages W_t from the hour labour supply, foreign and domestic denominated borrowings. The total revenue is used for consumption and paying the debt including the interests. Thus, the households' budget constraint is as follows:

$$P_tC_t = W_tH_t + T_t + \Pi_t + S_tD_{t+1} + B_{t+1} - P_t\frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 - (1+i_t^*)S_tD_t - (1+i_t)B_t. \quad (3.4)$$

The households choose the amount of non-traded and import consumption to maximize utility subject to budget constraint and the total composite demand, as follows:

$$C_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho} C_t, \quad (3.5)$$

$$C_{Mt} = (1-a)\left(\frac{P_{Mt}}{P_t}\right)^{-\rho} C_t. \quad (3.6)$$

The optimality conditions for households can be characterized by the following:

$$\frac{1}{1+i_{t+1}^*}\left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D})\right] = \beta \mathrm{E}_t\left[\frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}}\frac{S_{t+1}}{S_t}\right], \quad (3.7)$$

$$\frac{1}{1+i_{t+1}} = \beta \mathrm{E}_t\left[\frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}}\frac{S_{t+1}}{S_t}\right], \quad (3.8)$$

$$W_t = \eta H_t^\psi P_t C_t^\sigma. \quad (3.9)$$

Equation 3.7 and Equation 3.8 is the Euler equation arising from the purchase of foreign and domestic currency bonds, whereas Equation 3.9 is the labour supply equation.

3.3.2 Production Firms

Firms in the non-traded and export sectors operate with different production technology, with A_N and A_X the productivity parameter for the non-traded and the export sector, respectively. These final goods firms produce goods using labour hired from households at wages W_t, and capital hired from entrepreneurs, where they pay rent R_{Nt} and R_{Xt}. It is assumed that labour is mobile across sectors, therefore, the wage in non-traded and export sectors are equal. The production functions are standard as follows:

$$Y_{Nt}(i) = A_N K_{Nt}(i)^{\alpha} H_{Nt}(i)^{1-\alpha}, \tag{3.10}$$

$$Y_{Xt}(i) = A_X K_{Xt}(i)^{\gamma} H_{Xt}(i)^{1-\gamma}. \tag{3.11}$$

where α and γ are the share of capital in the non-traded sector and export sector, respectively. The firms' cost minimising behaviour implies the following optimality conditions:

$$W_t = MC_{Nt}(1-\alpha)\frac{Y_{Nt}}{H_{Nt}}, \tag{3.12}$$

$$R_{Nt} = MC_{Nt}\alpha\frac{Y_{Nt}}{K_{Nt}}, \tag{3.13}$$

$$W_t = P_{Xt}(1-\gamma)\frac{Y_{Xt}}{H_{Xt}}, \tag{3.14}$$

$$R_{Xt} = P_{Xt}\gamma\frac{Y_{Xt}}{K_{Xt}}. \tag{3.15}$$

Equations 3.12 and 3.14 define the optimal level of employment by the households for the non-traded and export sector, whereas Equations 3.13 and 3.15 determine capital demand in each sector. MC_{Nt} is the marginal cost of production in the non-traded sector, P_{Xt} is the price of traded export goods and because this sector is competitive then P_{Xt} is also the cost of production.

Capital goods firms produce capital (K_{Nt} in non-tradable sector and K_{Xt} in export sector) by combining new investment and existing capital stock (net of depreciation δ) to produce new unfinished capital goods which evolve according to Equations 3.16 and 3.17 and can also be seen as capital production functions.

$$K_{Nt+1} = \left[\frac{I_{Nt}}{K_{Nt}} - \frac{\psi_I}{2}\left(\frac{I_{Nt}}{K_{Nt}} - \delta\right)^2\right] K_{Nt} + (1-\delta)K_{Nt}, \tag{3.16}$$

$$K_{Xt+1} = \left[\frac{I_{Xt}}{K_{Xt}} - \frac{\psi_I}{2}\left(\frac{I_{Xt}}{K_{Xt}} - \delta\right)^2\right] K_{Xt} + (1-\delta)K_{Xt}. \tag{3.17}$$

There are investment adjustment costs so then the marginal return on investment in terms of capital goods is declining in the level of investment undertaken. Investment in new capital requires imports and non-traded goods in the same mix as the households' consumption basket. Therefore the nominal price of a unit of investment is P_t in either sector.

Competitive capital producers will ensure that the price of capital sold to entrepreneurs is

$$Q_{Nt} = \frac{P_t}{1 - \psi_I(I_{Nt}/K_{Nt} - \delta)}, \tag{3.18}$$

where Q_{Nt} is the price of capital.

3.3.3 Local Currency Price Setting

The firms in the non-traded sector operate as monopolistic competitors, choosing their output price to maximise profits. We follow Rotemberg's (1982) assumption of small direct price adjustment costs that apply to every non-traded goods firm. The existence of price adjustment costs makes firms adjust prices gradually to demand or marginal costs shocks.

As the firms are owned by households, then a firm will maximise its profit stream using the household's discount factor:

$$\Gamma_{t+1} = \beta \frac{P_t C_t^{\sigma}}{P_{t+1} C_{t+1}^{\sigma}}. \tag{3.19}$$

In particular, the objective of the firms is to maximise

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \Gamma_t \left[P_{Nt}(i) Y_{Nt}(i) - MC_{Nt} Y_{Nt}(i) - P_t \frac{\psi_{PN}}{2} \left[\frac{P_{Nt}(i) - P_{Nt-1}(i)}{P_{Nt-1}(i)}\right]^2 \right]. \tag{3.20}$$

The optimization problem of the firms is to choose price P_{Nt} to maximise profit stream (Equation 3.20). After imposing symmetry due to the assumption that all firms are alike, the optimization problem yields the optimal price setting problem as follows:

$$P_{Nt} = \frac{\lambda}{\lambda - 1} MC_{Nt} - \frac{\psi_{PN}}{\lambda - 1} \frac{P_t}{Y_{Nt}} \frac{P_{Nt}}{P_{Nt-1}} \left(\frac{P_{Nt}}{P_{Nt-1}} - 1 \right) + \frac{\psi_{PN}}{\lambda - 1} \mathrm{E}_t \left[\frac{\Gamma_{t+1}}{\Gamma_t} \frac{P_t}{Y_{Nt}} \frac{P_{Nt}}{P_{Nt+1}} \left(\frac{P_{Nt}}{P_{Nt+1}} - 1 \right) \right]. \quad (3.21)$$

The import firms buy foreign goods in foreign currency prices $S_t P^*_{Mt}$, and then sell the goods in domestic prices P_{Mt} to domestic market. The imported goods firms are also monopolistic competitors, so that they choose price P_{Mt} to maximise their profit stream. This mechanism causes the existence of delays between movements in the exchange rate and the imported goods prices adjustments. Thus, the imported good's price index for domestic consumers moves as follows:

$$P_{Mt} = \frac{\lambda}{\lambda - 1} S_t P^*_{Mt} - \frac{\psi_{PM}}{\lambda - 1} \frac{P_t}{T_{Mt}} \frac{P_{Mt}}{P_{Mt-1}} \left(\frac{P_{Mt}}{P_{Mt-1}} - 1 \right) + \frac{\psi_{PM}}{\lambda - 1} \mathrm{E}_t \left[\frac{\Gamma_{t+1}}{\Gamma_t} \frac{P_t}{T_{Mt}} \frac{P_{Mt}}{P_{Mt+1}} \left(\frac{P_{Mt}}{P_{Mt+1}} - 1 \right) \right]. \quad (3.22)$$

The interpretation of the imported good price index is that the monopolistic competitive importers set the price of domestic imported goods as a markup over the foreign price. In addition, importers face a quadratic adjustment cost so that they adjust their prices only gradually towards the desired price. The parameter from the quadratic adjustment costs ψ_{PM} thus acts as the degree of exchange rate pass-through.

3.3.4 Entrepreneurs

There are two types of entrepreneurs in the economy, one transforms the unfinished capital goods into finished capital goods for the use of the non-tradable sector, and the other produces finished capital goods for the traded sector. In order to produce finished capital goods, entrepreneurs borrow from foreign lenders. This reflects the liability dollarization problem of the emerging economies. The entrepreneurs' behaviour is similar to that proposed by Bernanke et al. (1999), which is extended into the open economy version in this study.

The mechanism of Bernanke et al. (1999) assumes the existence of an agency problem which makes external financing cost higher compared to internal funds. The output of the entrepreneur is subject to an idiosyncratic random outcome. The entrepreneur costlessly observes the outcome of their project, whereas the lender incurs monitoring costs to observe the entrepreneur's outcome. This reflects an information asymmetry problem. Depending on the outcome, the entrepreneur can decide whether to continue the project and thus repay the debt, or to default. If he defaults, the lender audits the loan and recovers the project outcome less monitoring costs.

The representation below is for the non-tradable sector, but the same representation also applies to traded goods sector. For both sectors, the entrepreneurs' demand for capital depends in the expected marginal return and the expected marginal external financing cost. The expected marginal return to capital (equal to the expected average return due to constant returns) is next period's ex-post gross output net of adjustment costs, normalized by the period t market value of capital as follows:

$$E_t R_{KNt+1} = E_t \left[\frac{R_{Nt+1} + \left[1 - \delta + \chi \left(\frac{I_{Nt+1}}{K_{Nt+1}} - \delta \right) \frac{I_{Nt+1}}{K_{Nt+1}} - \frac{\chi}{2} \left(\frac{I_{Nt+1}}{K_{Nt+1}} - \delta \right)^2 \right] Q_{Nt+1}}{Q_{Nt}} \right], \quad (3.23)$$

where R_{KNt+1} is the external funds rate and R_{Nt+1} is the marginal productivity of capital at t+1.

Lenders charge borrowers extra costs to cover the possibility of bankruptcy in order to receive a competitive return. This is how the lender deals with the existence of information asymmetry. Consequently, the marginal external financing costs are equal to the opportunity costs equivalent to the riskless interest rates plus the gross premium for external funds (i.e. the external finance premium). In the absence of the information asymmetry problem, the marginal external financing costs are equal to the riskless interest rates only.

The real return on capital is equal to the real cost on external funds:

$$E_t R_{KNt+1} = E_t \left[\left(1 + \frac{S_t \frac{D^e_{Nt+1}}{P_t}}{Z_{Nt+1}} \right)^{\omega} (1 + i^*_{t+1}) \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \right], \quad (3.24)$$

where ω is the elasticity of the external finance premium with respect to the leverage ratio $1 + \frac{S_t \frac{D^e_{Nt+1}}{P_t}}{Z_{Nt+1}} = \frac{K_{Nt+1} Q_{Nt}}{Z_{Nt+1}}$. If the ω is equal to zero, then this relationship collapses to a condition where capital rate of return is equal to the cost of funds, and thus there is no capital market frictions.

The gross external finance premium depends on the borrowers leverage ratio:

$$premium_t = \frac{E_t R_{KNt+1}}{(1+i^*_{t+1})\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}} = E_t\left[\left(1+\frac{S_t\frac{D^e_{Nt+1}}{P_t}}{Z_{Nt+1}}\right)^{\omega}\right] = E_t\left[\left(\frac{K_{Nt+1}Q_{Nt}}{Z_{Nt+1}}\right)^{\omega}\right]. \quad (3.25)$$

$\frac{D^e_{Nt+1}}{P_t}$ denotes the share of total real debt denominated in foreign currency hold by entrepreneurs and it is given by:

$$\frac{D^e_{Nt+1}}{P_t} = \frac{1}{S_t}(Q_{Nt}K_{Nt+1} - Z_{Nt+1}). \quad (3.26)$$

Equation 3.24 shows that the entrepreneurs decision to acquire additional capital financed by debt D^e_{Nt+1} leads to a higher leverage ratio, $\frac{K_{Nt+1}Q_{Nt}}{Z_{Nt+1}}$, inducing a higher external finance premium, and thus a higher overall marginal cost of finance R_{KNt+1}. Due to this higher marginal cost of finance, entrepreneurs' demand for capital is less than the perfect capital market case.

It is important to note that, this gross external finance premium depends only on the aggregate leverage ratio and not on any entrepreneur-specific variables. The above relationship shows that in general, the external finance premium depends negatively on the aggregate net worth of entrepreneurs: the greater share of the net worth is, the lesser is the probability of default and bankruptcy cost, and hence the smaller is the external finance premium.

This relationship also provides the financial friction, which is key. That is, the financial position of the entrepreneur (i.e. collateral) influences the marginal cost of funds, and therefore, the demand for capital. In addition, the price of capital Q_{Nt} is also important in affecting the leverage ratio and collateral.

The entrepreneurs are assumed to survive for the next period with probability ν. This assumption is to ensure that the entrepreneurs will not be able to accumulate enough net worth such that they can fully finance the new capital acquisition themselves. Thus, the entrepreneurs' net worth is defined as follows:

$$Z_{Nt+1} = \nu\left[R_{KNt}Q_{Nt-1}K_{Nt} - (1+i^*_t)(Q_{Nt-1}K_{Nt} - Z_{Nt})\frac{S_t}{S_{t-1}}\right]. \quad (3.27)$$

Entrepreneurs going out of business at time t consume their remaining resources:

$$C^{e}_{Nt} = (1 - \nu)[R_{KNt+1}Q_{Nt+1}K_{Nt} - (1 + i^{*}_{t-1})(Q_{Nt-1}K_{Nt} - Z_{Nt})\frac{S_t}{S_{t-1}}]. \quad (3.28)$$

3.3.5 Monetary Policy

The monetary authority conducts monetary policy by adjusting nominal interest rates according to an interest rate rule:

$$1 + i_{t+1} = \left(\frac{P_t}{P_{t-1}}\frac{1}{\bar{\pi}}\right)^{\mu_\pi}\left(\frac{S_t}{\bar{S}}\right)^{\mu_S}(i_t)^{\mu_i}\vartheta_t. \quad (3.29)$$

The parameter μ_π defines the importance of the CPI inflation rate which is targeted around the target level $\bar{\pi}$. In addition, the parameter μ_S shows the degree of interest rate adjustment by the monetary authority upon variations in the exchange rates around the target level $\bar{S}$, while μ_i is the degree of policy rate adjustment around an interest rate target level i. The monetary policy shock is described by ϑ_t. We do not include the output of the interest rate rule following the finding by Schmitt-Grohé and Uribe (2005) who find that the output coefficient in the optimized interest rate rule which is close to zero.

3.3.6 Equilibrium

The market clearing condition for non-tradable goods is defined as total demand coming from consumption of households, firms, and entrepreneurs, including demand which is required to pay the costs of price adjustment (of both the non-tradable and foreign exporters), monitoring, and foreign bond adjustment as follows:

$$Y_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho}(C_t + I_{Nt} + I_{Xt} + C^{Ne}_t + C^{Xe}_t + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + \frac{\psi_{PN}}{2}\frac{(P_{Nt} - P_{Nt-1})^2}{P^2_{Nt-1}} + \frac{R_{KNt}Q_{Nt-1}K_{Nt}}{P_t}\phi_{Nt} + \frac{R_{KXt}Q_{Xt-1}K_{Xt}}{P_t}\phi_{Xt} + \frac{\psi_{PM}}{2}\frac{(P_{Mt} - P_{Mt-1})^2}{P^2_{Mt-1}}). \quad (3.30)$$

The households labour supply must be divided between the two sectors, so that labour market clearing condition implies:

$$H_{Xt} + H_{Nt} = H_t. \quad (3.31)$$

3.3.7 Autoregressive Shocks

We introduce two exogenous shocks: foreign interest rate shock (i.e. a decrease in i_t^*) and domestic monetary policy shock (a decrease of ϑ_t).

All the shocks follow a first-order autoregressive process:

$$i_t^* = (i_{t-1}^*)^{\rho_{i^*}} \exp(\varepsilon_{i^*}) \tag{3.32}$$

$$\vartheta_t = (\vartheta_{t-1})^{\rho_\vartheta} \exp(\varepsilon_\vartheta) \tag{3.33}$$

3.4 Calibration

We follow the literature in setting well-known deep parameters. The steady state rate of depreciation of capital (δ) is set equal to 0.025 which corresponds to a rate of depreciation equal to 10 percent annual; the discount factor β equals 0.945, which corresponds to an annual rate in the steady state of 5.75 percent. The inverse of elasticity of substitution in consumption is 2 following Devereux et al. (2006) and Ozkan and Unsal (2017). The steady state share of capital in the non-tradable output (α) is equal to 0.3, while the steady state share of capital in the tradable output is set equal to 0.6 as in Merola (2010). The investment adjustment cost χ takes a value of 12. The probability ν that entrepreneurs will survive for the next period is set equal to 0.94, therefore on average entrepreneurs may live for 37 years. Following Gertler et al. (2007), the elasticity of substitution between domestic goods and imported goods in consumption (ρ) is set equal to 1.

Some of the parameters used in the model are calibrated using the values utilized by similar models used by Bank Indonesia. According to Indonesian data, the relative steady state size of the non-tradable and the tradable (export) sectors are Y_N 0.77, whereas Y_X 0.23, respectively. The share of non-tradable goods in CPI (a), is set equal to 0.63 following Indonesian figures in Harmanta et al. (2014). The inverse of elasticity of labour supply (ψ) and the coefficient of labour in utility (η) are both set equal to 1. The domestic retailer's profit margin (price markup) in Indonesia is 18%, as in Harmanta et al. (2014). This value implies the steady state value of the elasticity of substitution between varieties of goods (λ) is set equal to 6.5, in both non-tradable an import sector. Keen and Wang (2007) generate a relationship between Rotemberg price adjustment cost ψ, the constant fraction of re-optimizing firms $(1-\theta)$, the elasticity of substitution between varieties λ (or equivalently the price markup ratio $\frac{\lambda}{1-\lambda}$), and the discount factor β as follows:

$$\psi = \frac{\lambda(1-\theta)}{(1-\theta)(1-\beta\theta)} \tag{3.34}$$

According to Harmanta et al. (2014), the Calvo parameter θ of firms not re-optimizing for non-traded, import, and export sectors in Indonesia are 0.4, 0.7, and 0.6 respectively. With price markup of 18% and discount factor 0.945, these values imply price adjustment cost of 5.89, 37.91, and 19.05 in the non-traded, import, and export sector respectively which are then used in this study. The investment adjustment cost is at 5 and bond adjustment cost is 0.0007.

We follow Devereux et al. (2006) for the implied savings rate of entrepreneurs equal to 0.94. The monetary authority is assumed to implement an inflation targeting framework where stable inflation is aimed, and the exchange rate is floated. Therefore, the parameters of the policy rule assume that μ_π is 20, whereas μ_S is 1. Shocks are persistent: the autoregressive parameter is assumed to be equal to 0.9 for all the shocks. Finally, for both sectors, the elasticity of risk premia to the leverage ratio (ω) is assumed to be equal to 0.02. The full list of parameter values is presented in Table 3.1.

3.5 The Impact of US Federal Reserve Monetary Policy Easing on Emerging Economies

In order to study the impact of foreign monetary policy easing, we consider a decrease in the world interest rate (i_t^*) as the first shock. We then compare the outcomes of the shock under two conditions of an economy with high and very low financial friction, which is implied in the value of ω i.e. the elasticity of the external finance risk premium with respect to the leverage ratio. As in Merola (2010), an economy with a financial friction is assumed to have the value of $\omega = 0.015$, while $\omega \to 0$ for an economy with very low financial friction. The second shock is negative domestic monetary policy rate shock ϑ_t in order to study whether monetary policy contagion in which monetary policy easing in the foreign economy is followed by domestic policy easing is an effective response for the domestic economy.

Figure 3.4 plots the impulse response of a set of domestic variables to a one standard deviation negative shock to the foreign interest rate. The economy is assumed to have fully flexible exchange rates. There is a monetary authority, which implements a standard inflation-targeting Taylor Rule type of monetary policy. In a small open economy featuring substantial liability dollarization and financial friction, a shock to foreign interest rates may affect domestic stability through two main channels. First, entrepreneurs borrow externally with the rate determined by the foreign interest rate. Second, the foreign interest rate is the 'price' for the international risk-sharing transaction where consumers-households involve in.

On impact, the foreign interest rate reduction widens the wedge between domestic and foreign interest rates, causing the domestic financial market to be more attractive to foreign investors. At the same time, capital inflows increase as shown by the balance of payment dynamics, which is the difference between foreign asset invested in the domestic economy and domestic asset invested abroad. Higher capital inflows lead to the appreciation of the domestic currency as shown in Figure 3.4, although the appreciation is relatively minor. The exchange rate appreciation reduces the competitiveness of domestic goods, decreasing the output of the export sector.

The foreign interest rate reduction shocks can be seen as a cheaper cost of investment, indicated by the marginal rate of return on capital. Hence, a foreign interest rate reduction causes a drop in the expected return on capital for the entrepreneurs. As a result, there is a drop in the external finance premium which means, borrowing from outside becomes less expensive for the entrepreneurs-borrowers compared to raising fund internally.

The lower cost of investment induces entrepreneurs to borrow more, thus we see an increase in entrepreneurs debt which reaches a peak four periods after the initial shock, but then gradually falls back to the steady state level in the long run. This supports the international risk-taking channel of monetary policy, as argued by Bruno and Shin (2015a), that lower US dollar interest rates which cause an appreciation of exchange rates of the other economies increase banks' ability to lend more in US dollars to firms with the same level of local currency loan, thus increasing risk-taking behaviour in financial markets. As entrepreneurs increase their foreign borrowing due to cheaper borrowing costs, their level of investment is enlarged. As a result, the capital production in the economy enlarges, although the magnitude is not very substantial compared to the increase in entrepreneurs debt. At the same time, asset prices increase on impact. This improves profits received by the entrepreneurs, and thus their

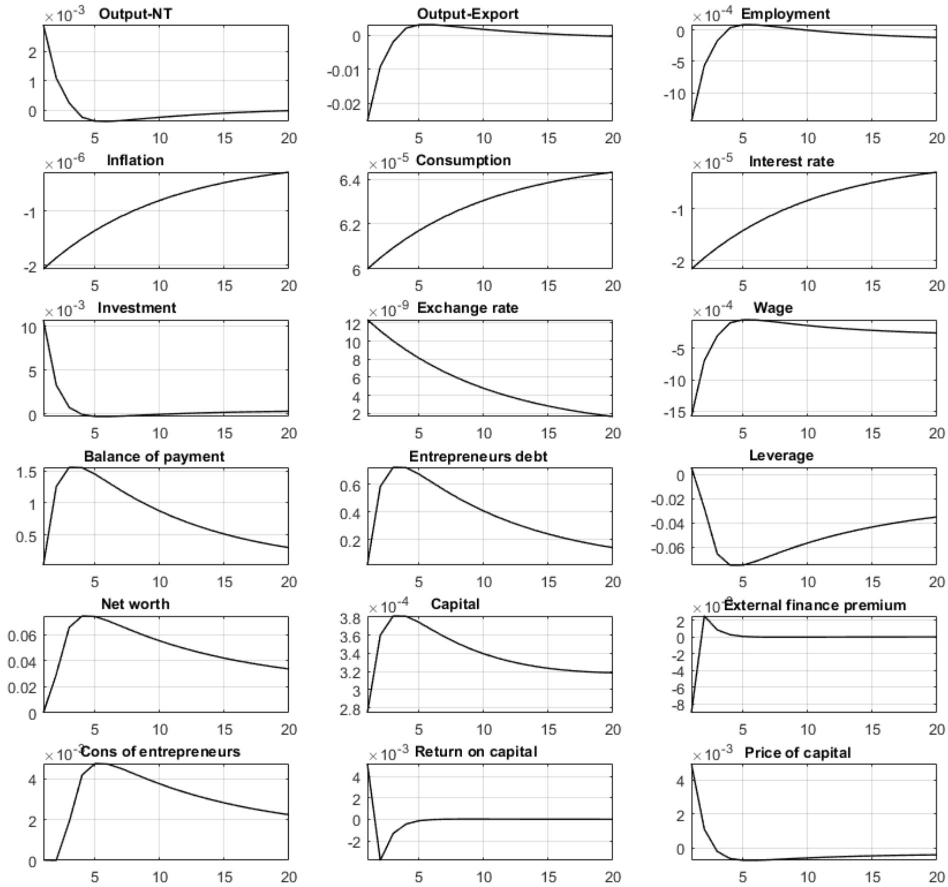


Figure 3.4: Negative shock to foreign policy rate

net worth also increases. Entrepreneurs' leverage gradually reduces and reaches the bottom level at around four periods after the shock. Lower leverage and increased profitability for the entrepreneurs lead higher entrepreneurs' consumption up to four periods following the shock.

The foreign short rate reduction influences production in the non-tradable and export-oriented goods production differently. This is mainly due to different ratio of production factors in the two sectors. While non-tradable is labour-intensive, the tradable (export) sector is more capital-intensive. Although capital production enlarges in this economy, higher production materializes in the labour-intensive non-tradable sector but not in the export sector.

The export goods production decreases following the lower foreign rates because appreciation of domestic exchange rate makes the domestic export product more expensive. On the contrary, the foreign rates reduction appears to increase non-tradable production. In comparison, the reduction in the output of the export sector is more than the increase in the output of the non-tradable sector. The different effects on the two different sector is because, firstly, the ability of entrepreneurs to borrow more externally allows the economy to produce more capital. Secondly, the non-tradable output is sold domestically, thus its price does not depend on the exchange rate. Thus, the extent to which lower foreign interest rate impacts the domestic economy will depend on the proportion of non-tradable goods and export goods production in the economy, as well as their structure of production factors.

In our calibrations, the drop in the export production appears to outweigh the positive effect of higher non-tradable goods production. As can be seen, there is an increase in unemployment rate, and a drop in wage rates and consumption although consumption increases in the long run. The lower production costs and exchange rate appreciation reduces inflation rate on impact. This makes the domestic monetary authority to reduce domestic interest rates. Hence, when the exchange rate is flexible and monetary authority implements an inflation rate targeting regime, a monetary policy relaxation in the advanced country tends to be followed by monetary policy relaxation in the domestic emerging economy.

3.6 The Impact of Financial Frictions on Domestic Economy

Figure 3.5 shows the divergent paths of impulse responses from a negative shock in foreign interest rates in two distinct economies with different levels of financial frictions. The black line represents an economy with the low level of financial frictions (benchmark), while the red

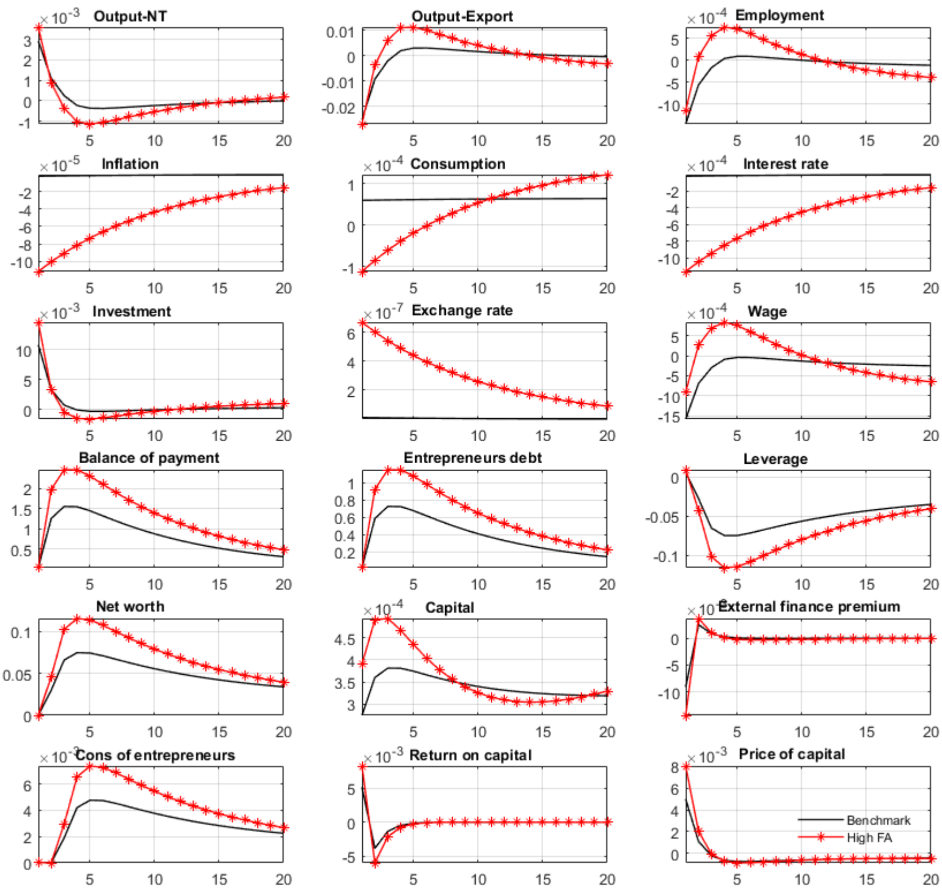


Figure 3.5: Negative shock to foreign policy rate

Note: Black line is the low financial friction economy (benchmark); red asterisk line is the high financial friction economy.

asterisk line represents a higher level. An emerging economy with higher financial frictions is the economy where information asymmetry is more severe where the foreign lender is less able to observe the outcome of the investment project. The implication of higher financial friction is that the external finance premium is even more dependent on the entrepreneurs' leverage ratio. In other words, for the same level of foreign borrowing, an economy with higher financial friction will have to pay more external finance premium.

The figures show that the higher the level of financial friction is, the more intensified impact the foreign interest rate shock has on the entrepreneurs' leverage, net worth, consumption, and capital. The emerging economy with higher financial friction is more sensitive to foreign interest rate changes. Lower foreign rates are perceived as a reduction in risk premium leading to a lower external finance premium. As the external finance premium reduces, cost of investment decreases more significantly in high financial friction economy compared to the lower one. The exchange rate appreciates even more when financial friction is higher. As a result, entrepreneurs are more willing to take more risks by borrowing more from the rest of the world, causing more domestic capital inflows.

As there is more foreign borrowing by the entrepreneurs, investment and thus capital production is increased even more in the high financial friction economy. Furthermore, as entrepreneurs profitability is higher, their aggregate net worth is increased, leading to lower leverage.

The exchange rate appreciation reduces domestic products' competitiveness. Thus the output of export product diminishes on impact. Nevertheless, there is more capital production in the high financial friction economy such that the capital-intensive export sector in this economy recovers better. In fact, the magnitude of the increase in the export production dominates reduction in the non-tradable sector. Hence, the economy produces more in total, implying higher income per capita. This increase in production allows more employment and higher wages.

3.7 Domestic Monetary Policy Reaction ϑ_t Following Foreign Monetary Policy Relaxation

In Section 3.5 the impulse responses show that a monetary authority of an emerging economy with a flexible exchange rate regime and inflation targeting framework will lower the domestic policy rate in response to a foreign monetary policy relaxation. In this section, we discuss the implication of a monetary easing reaction by the domestic economy following the foreign rate easing. We would like to see whether the domestic policy rate reduction is able to neutralize the impact of monetary easing in the centre economy on the emerging economy condition.

Figures 3.6 plot the impulse responses of domestic macroeconomic variables to a negative domestic monetary policy shock. The monetary easing shock reduces the marginal return on capital (as a proxy for the cost of capital) on impact but then increase in around the third quarter. Domestic monetary policy rate easing also reduces interest rate differential between the advanced and the emerging economy. This slows down the capital inflows as there is a smaller magnitude of the increase in the balance of payment and the entrepreneurs' debt. If financial friction is higher, then this turns to capital outflows in the medium run. The reduction of capital inflows might be an expected impact if the capital inflows are perceived as destabilizing and there is a tendency of asset price bubbles.

From the perspective of demand and supply of capital, we expect two main but opposing impacts coming from a reduction in domestic interest rates. On the one hand, a decrease in domestic interest rates should be preferable by the entrepreneurs as the cost of investment becomes cheaper. On the other hand, lower domestic interest rates mean lower profitability for foreign lenders as can be seen from the increase of the external finance premium. Furthermore, to produce the capital, entrepreneurs borrow fully from foreign resources and thus the extent to which entrepreneurs depend on foreign lenders is high.

As the cost of investment is cheaper under lower domestic interest rate, entrepreneurs are willing to borrow more and thus able to produce more. Hence, there is still an increase in the entrepreneurs' debt, although the increase in the debt reduces back to the steady state level quite rapidly. In the short run, there is an improvement in entrepreneurs' net worth and their consumption but this effect subsides also rapidly and the level in entrepreneurs' net worth returns to the steady state in four quarters after the shock. In the medium to long run, the impact of lower domestic interest rate on reduced foreign lenders' profitability comes into effect. In particular, because the rate of return for investing in the emerging market is lower, foreign lenders reduce the level of lending in aggregate. As a result, entrepreneurs invest less and thus capital production also decreases, although the reduction in the investment and capital production is quantitatively a lot less than the foreign lenders reduction in the level of foreign lending. In the medium to long run, the profitability of the entrepreneurs is undermined, leading to a reduction in the net worth and consumption of entrepreneurs. This partly reflects a liability dollarization problem where domestic business dependency on foreign borrowings makes them prone to changes in interest rates differential and exchange rates fluctuations.

As in the result of the positive interest rate shock in the foreign economy, the negative shock to domestic policy rate also affects production in the non-tradable and export sector differently. Again, this is due to the different ratio of production factors in the two sectors. A lower interest rate decreases production in the non-tradable sector on impact, but increases output in the export sector. The dynamics of the export goods' production seems to be affected more by the dynamics of the return on capital as this sector is capital-intensive. In the short

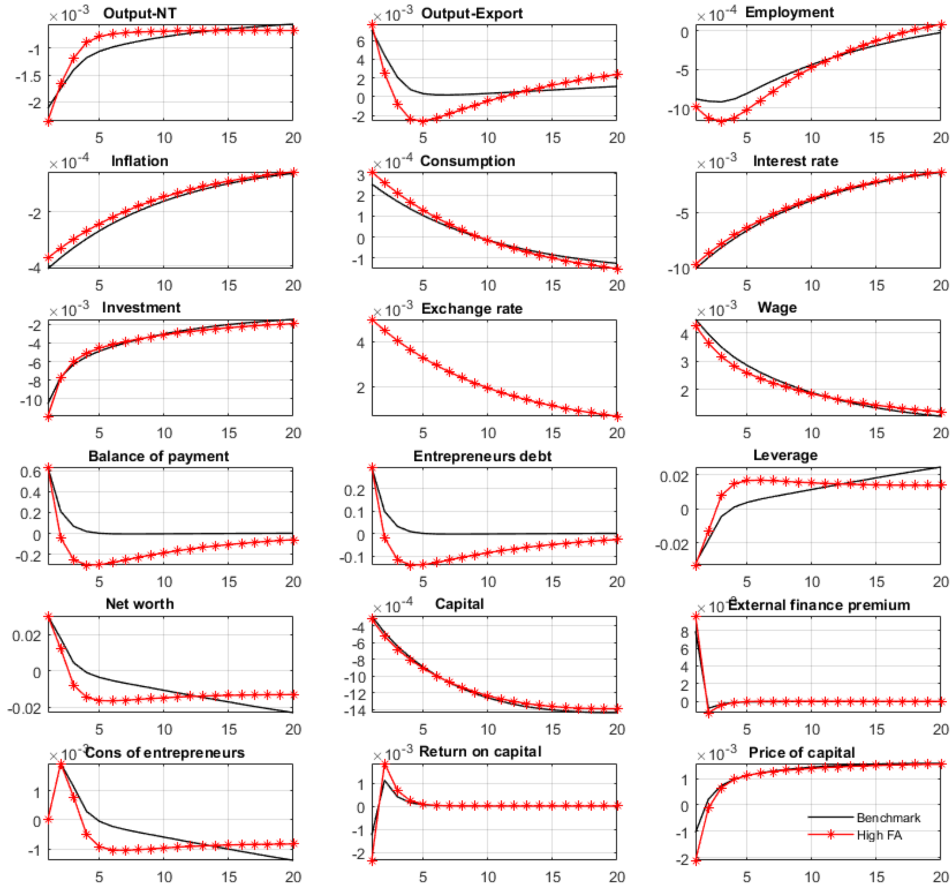


Figure 3.6: Negative shock to domestic policy rate

Note: Black line is the low financial friction economy (benchmark); red asterisk line is the high financial friction economy.

run, a drop in the return on impact reduces the cost of capital and thus increases the production in the export sector. However, this effect does not persist in the medium to long run as the export production reduces back to the steady state level only in around four quarters after the shock. Furthermore, the reduction of the export goods' production is worse the higher the financial accelerator mechanism is. The slowing down of the export sector in the medium terms seems to be caused by a reduction in the supply of capital as capital production sector deteriorates.

The negative shock in domestic interest rates appears to have a mix effect on the real sector. In particular, there is a reduction in the employment rate, most likely due to the reduction in the non-tradable goods production which appears to reduce labour demand in aggregate. The effect of reduction in the non-tradable sector on the labour market is greater than the effect coming from the export goods' production because the non-tradable sector is labour-intensive. Apart from that, we observe a reduction in the inflation level which boosts the aggregate consumption level. The increase in the consumption level is also supported by the higher wage.

To sum up, a domestic monetary policy relaxation appears to be able to slow down capital inflows, a desirable effect when the inflows are perceived to be destabilizing. However, if the capital inflows are used to fund investment projects as in this model framework, the reduction in capital inflows can be detrimental. In particular, a drop in domestic interest rates leads to lower capital inflows which reduces domestic capital production and affects the production sector negatively in general, although the reductions of capital production and investment are less than reductions in capital inflows. This is a typical liability dollarization problem where the high dependency of entrepreneurs on foreign lending makes capital production sensitive to changes in interest rate differential as well as exchange rate fluctuations. This effect is also enlarged in an economy where financial friction is higher. The extent to which the aggregate output production is affected depends on the relative scale of the capital-intensive sector (the export sector) and the labour-intensive sector (the non-tradable sector). If the capital-intensive sector is relatively large in the economy compared to the other sector, then the effect of domestic interest rate reduction to output production in aggregate is worse. With regard to the impact on inflation, if inflationary pressures and asset price bubbles following the foreign interest rate easing is more of a concern, then responsive domestic monetary policy might ease the pressure of the foreign monetary policy on the domestic economy.

3.8 Conclusion

This study aims at analysing how external challenges combined with several common features of an emerging small open economy affect domestic macroeconomic variables and financial stability. In particular, we introduce a negative foreign interest rate shock in order to imitate the periods following the global financial crisis 2007-8. In this period, the US Federal Reserve introduced an aggressive reduction in monetary policy rate followed by unconventional monetary policy easing in the form of large-scale asset purchases as analysed in the previous chapter. We then analyse whether an emerging economy's strategy of reducing domestic interest rate could stabilize the pressure from the foreign rate decrease.

We find that a foreign monetary policy reduction tends to increase capital inflows in emerging economies, particularly due to higher foreign borrowings by entrepreneurs. Foreign rates reduction widens the wedge between domestic interest rates and foreign interest rates and induces a domestic exchange rate appreciation, which makes the cost of investment in domestic economy cheaper. As the external finance premium decreases, domestic entrepreneurs take more risks by borrowing more and then invest more in capital production although the increase of investment in capital production is less than the increase in capital inflows. This supports the international risk-taking channel of monetary policy. Although lower foreign rates appear to profit entrepreneurs, the export goods production reduces due to lower export product competitiveness following exchange rate appreciation. On the other hand, output in the non-tradable sector increases. Consumption is also increasing in the long run.

A higher financial friction exaggerates the fluctuations of entrepreneurs' activity in producing capital. An emerging economy with higher financial friction is more sensitive to foreign interest rate changes. In particular, in the economy where financial friction is high, a foreign monetary policy relaxation decreases the cost of investment more significantly making entrepreneurs more willing to take risks by borrowing more from overseas market. As a result, the economy is less stable as a higher degree of financial friction magnifies volatilities of output, consumption, and employment rate.

The implications of a responsive domestic monetary policy easing depend on some factors, e.g. the scale of liability dollarization problem, the ratio of the capital-intensive sector to the rest of the economy, and the main concern following the foreign negative interest rate shocks. A domestic monetary policy reduction appears to be able to slow down capital inflows, which is desirable when capital inflows are destabilizing and mainly goes to financial markets like stocks or bonds. If capital inflows are the source of funding for capital investment projects however, the effect of domestic monetary easing can be detrimental. This is a typical liability dollarization problem where the high dependency of entrepreneurs on foreign lending makes capital production sensitive to changes in interest rate differential and exchange rate fluctuations. Moreover, the effect is worse to the rest of the economy if the relative size of the capital-intensive sector is large. In particular, a slow down in capital inflows disrupts capital production leading to a reduction in the capital-intensive sector production. If inflationary pressures and asset price bubbles following the foreign interest rate reduction is more of a concern, then responsive domestic monetary policy might ease the pressure of the foreign monetary policy on the domestic economy.

These findings underline the reason behind domestic monetary policy easing response by emerging monetary authorities following large monetary relaxation by the centre economy: the domestic policy stance is expected to reduce destabilizing capital inflows, avoid domestic currency appreciation, and ease the domestic inflationary pressures. Nevertheless, this policy stance has negative consequences if the inflows are used for capital investment project and the capital-intensive sector is large in the economy. Hence, an emerging economy might need to consider alternative policy measures in order to strengthen domestic economy against foreign financial and policy spillover, for instance by implementing macroprudential policy, as analysed thoroughly in the next chapter.

Table 3.1: List of parameters and the values

		Parameters Value
σ	Inverse of elasticity of substitution in consumption	2
β	Discount factor	0.945
ρ	Elasticity of substitution between non-traded and import goods in consumption	0.9
λ	Elasticity of substitution between varieties (same across sectors)	6.5
η	Coefficient on labour in utility	1
ψ	Elasticity of labour supply	1
γ	Share of capital in export sector	0.6
α	Share of capital in non-traded sector	0.3
δ	Quarterly rate of capital depreciation	0.025
a	Share on non-traded goods in CPI	0.62
ψ_{PN}	Price adjustment cost in the non-traded sector	5.89
ψ_{PM}	Price adjustment cost in the import sector	37.91
ψ_I	Investment adjustment cost	20
ψ_D	Bond adjustment cost	0.0007
ν	Aggregate saving rate of entrepreneurs	0.94
Ω	Share of households' labour in the effective labour	0.95
$\mu_{\pi N}$	Monetary authority's control on the non-traded goods inflation rate	1
μ_{π}	Monetary authority's control on the CPI inflation	1
μ_S	Monetary authority's control on the exchange rate	1

Chapter 4

How Should Emerging Markets Defend Against the Fed Lift-off?: The Role of Macroprudential Policy

4.1 Introduction

The US Federal Reserve (Fed) has played a leading role in shaping the global monetary responses to the 2007-08 financial crisis through both conventional and unconventional monetary policy. This has taken the form of cutting interest rate to near zero levels and enacting a large scale asset purchasing program, widely known as quantitative easing (QE), with clear implications for the global economy. The emerging economies (EEs) have greatly benefited from the resulting overly expansionary US monetary policy. Excess liquidity created by QE led to substantial capital flows into these economies at the back of the very low US interest rates, leading to EEs dollar-denominated borrowing to double since 2009 (see, for example, Tarashev et al. (2016)).[1]

It is, therefore, not surprising that the reaction of EEs to the announcements of Fed's unwinding QE had been dramatic. Major fluctuations in both the stock and currency markets across EEs were observed throughout May 2013-October 2014 over which the Fed first cut back and then ended its asset purchases. Similarly, the Fed lift-off - ending the near-zero interest

[1] In its Global Financial Stability Reports, the International Monetary Fund (IMF) repeatedly warn countries with substantial dollar-denominated debts of severe risks from higher US interest rates.

rate policy- that started with the first rise in December 2015 led to a substantial withdrawal of capital from EEs. Given the scale of foreign currency exposure, as mentioned above, it is clear that there are significant risks from the impending US interest rate rise not just for the indebted countries but also for the global economy as a whole.

Although the significance of the Fed lift-off is well-understood in policy circles, there is, as yet, no systematic analysis of how best a country can respond to an external shock of the kind presented by the US move towards contractionary monetary policy. The growing literature on the spill-overs of US post-crisis monetary policy on other economies is currently of empirical nature and focusses on main drivers of the resulting capital inflows to other countries (Chen et al. (2012b) and Ahmed and Zlate (2014)); the impact of interest rate setting in other countries (Takáts and Vela (2014)); and the impact of announcements regarding exit from QE (Eichengreen and Gupta (2015) and Aizenman et al. (2014)).

This paper examines how a small open economy can defend against a foreign interest rate rise by presenting a comparative analysis of a set of macroprudential policies (MaP) which are widely adopted across the world since the global financial crisis. We first explore how a rise in foreign interest rate impacts on the domestic economy. We then propose a set of macroprudential policy measures and systematically evaluate the effectiveness of each measure in the domestic economy's defense against the foreign rate rise. Subsequently, we analyse whether the level of financial integration, the type of exchange rate regime and the degree of financial development alter the effectiveness of macroprudential policies. As a measure of effectiveness, we calculate the volatilities of key macroeconomic and financial variables, and examine whether a combination of monetary policy with a particular MaP is effective in dampening fluctuations in those variables.

Macroprudential measures have been widely used by both advanced and emerging market countries in the aftermath of the 2008-09 global financial crisis. According to a joint report by the IMF, the Financial Stability Board (FSB) and the Bank for International Settlements (BIS) in 2016, MaP is the use of primarily prudential tools to limit systemic risks across the financial system (IMF-FSB-BIS, 2016). A central element in this definition is the notion of systemic risk, i.e. the widespread disruptions in financial intermediation caused by the failure of part or all of the financial system, with serious consequences for the real economy (IMF-FSB-BIS, 2016). Cerutti et al. (2017) document that macroprudential policies are used more frequently in emerging economies than in advanced economies, suggesting higher exposure in the former to external shocks given the less developed financial systems with more 'market failures'.

Another empirical regularity has been the use of a wide range of macroprudential institutional arrangements and policies, suggesting that there is no "one-size-fits-all" approach (IMF-FSB-BIS, 2016). Widely adopted tools towards addressing the systemic risk include (a) capital-based tools; (b) asset side tools/loan restrictions; and (c) liquidity-related tools (CGFS 2012, ESRB 2014, IMF 2014).

In this paper, we consider a set of Taylor-type macroprudential measures that are tied to a range of financial indicators as their bases for the macroprudential tax/subsidy, focussing on lender's side restrictions. While the MaP on the borrower-side are also implemented in some EEs, this type of prudential policies has been more frequent in the advanced economies (Cerutti et al., 2017). The lender-side of macroprudential policies tackle key externalities and market failures, directly affecting financial institutions' ability and willingness to lend to the real sector. In our model, there are global banks located in the centre economy which lend internationally to local banks in the EE. This cross-border bank lending and borrowing activities serve as a key channel for international propagation of shocks from the advanced to the emerging economy linking monetary policy in the centre economy with the leverage of the global banks and hence to capital flows into the recipient economies.

Our findings can be summarized as follows. First, we show that macroprudential policy targeting foreign bank borrowing and loan-to-GDP ratio are very effective in limiting the effects of a foreign interest rate rise on a small open emerging economy. Secondly, we find that the effectiveness of macroprudential policy improves under restricted capital mobility, reducing fluctuations in most financial variables quite significantly. This is in line with the International Monetary Fund (IMF) report in 2011 stating that the application of prudential measures or capital controls in response to capital inflows may be appropriate for several countries based on their current circumstances (IMF, 2011). In the end of 2006 Thailand adopted a capital mobility restriction in the form of a withholding tax on non-resident interest earnings and capital gains applied only to state bonds. The withholding tax appears to have had positive impact in slowing volatile portfolio inflows, albeit temporarily. This is similar with South Korea experiences with adopting macroprudential policy aiming at foreign borrowing. In November 2009 the South Korean authorities implemented a more stringent foreign currency liquidity standards, continued by the reduction of the banks' short-term external debt in June 2010.

The measures were able to reduce the banking system vulnerabilities by preventing banks' external debt from returning to pre-crisis levels, although the measures could not be applied on the off-shore banks using the non deliverable forward contracts (IMF, 2011).

In the long run, however, impediments to capital mobility prevents the economy from reaping the benefits in the form of lower cross-border borrowing rate and greater capital inflows. The choice of the exchange rate regime also plays a key role in the impact of the Fed lift-off on the domestic outcomes, with the unfavourable impact of the foreign interest rate rise on the domestic outcomes greater under a fixed exchange rate regime. Interestingly, however, limiting the exchange rate flexibility improves the effectiveness of the macroprudential policy. In sum, our results highlight the importance of adopting a combination of policies against global financial disturbances including macroprudential measures, restrictions to capital flows and restricting exchange rate flexibility.

The rest of the paper is organized as follows. Section 2 sets out the main features of the benchmark model for both the core (advanced) and the peripheral (emerging) economy as well as the specifications of the policy formulation. Section 3 and 4 discuss our calibration strategy and the policy experiments. Section 5 presents our analysis of the implications of the Fed lift-off on the domestic economy as well as the effectiveness of macroprudential policy on limiting such effects. Sections 6 and 7 explore the role of varying the degree of financial integration and the type of the exchange rate regime in the emerging economy on both the implications of the foreign interest rate rise and the effectiveness of macroprudential policy in defence against those implications. Section 8 repeats the same exercise for the role of financial sector development. Finally, Section 9 presents the main conclusions.

4.2 The model

Our framework is a New Keynesian dynamic stochastic general equilibrium (DSGE) two-country - core-periphery- model that features financial institutions *á la* Gertler and Karadi (2011); interactions between international financial institutions in the core economy (the global banks) and those in the domestic EE (the local banks) as in Banerjee et al. (2016). The centre (core) country (CC) is assumed to be large relative to the peripheral country.

Each economy is populated by households, production firms, capital goods producers, and financial intermediaries (banks). Although asymmetric in size, the domestic and the advanced economy (AE) share the same market structure, technology, and preferences for consumption and capital goods. There is a global capital market for one-period risk-free bonds EE households participate in. CC households deposit with the global banks at the risk-free rate, and can hold one-period nominal CC government debt, which may also be traded in international capital markets.[2] Global banks use the deposits together with their own net worth to invest in risky CC technologies as well as in emerging market banks. The fund EE banks receive from the global bank together with their own net worth are used to fund capital production in the EE.

Banks in both countries finance purchases from the capital goods producers, and rent this capital to goods producers in respective countries. The model contains two levels of agency constraints; global banks must satisfy net worth requirement to be able to borrow from the CC's households, and in turn, the local EE banks must satisfy capital requirements to secure borrowing from international banks. In both countries, production firms use rented capital and labour to produce final goods which are sold to retailers. A fraction of EE final goods is exported to the CC, and *vice versa*. In essence, the EE mirrors the AE except that the EE households do not invest in EE banks, but rather engage in international consumption smoothing through the purchase and sale of centre currency denominated nominal bonds. The net worth constraint faced by banks in both the EE and AE are motivated along the lines of Gertler and Karadi (2011).

In what follows, we present the key features of the model for both economies. A full list of model equations is represented in the Appendix.

4.2.1 The Emerging Economy (EE)

4.2.1.1 Households

A fraction n of the worlds' population lives in the EE where households consume, work, and act separately as bankers. The household members that are bankers have a probability θ of continuing as bankers upon which they will accumulate net worth. There is a probability $1-\theta$ of exiting the banking profession and rejoining the household as a consuming/working member. In every period, there are non-bank household members randomly assigned as bankers thus

[2] The terms 'centre country (CC)' and 'advanced economy (AE)' are used interchangeably throughout this paper.

keeping the population of bankers constant. Although the EE households do not have access to investment in local financial firms, they can purchase international bonds (B_t^e). Households receive utility from consumption and provide labour to the production firms. The households also own the firms in the economy and therefore receive profits from these firms.

An infinitely lived representative EE's household seeks to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{e(1-\sigma)}}{1-\sigma} - \frac{H_t^{e(1+\psi)}}{1+\psi} \right), \tag{4.1}$$

where superscript e is used to denote variables for EE, C_t^e is a composite consumption index, H_t^e is hours of work, E_t is the mathematical expectation conditional upon information available at t, β is the representative consumer's subjective discount factor where $0 < \beta < 1$, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution and $\psi > 0$ is the inverse elasticity of labour supply. We assume, in addition, that within each basket goods are differentiated and within-country elasticities of substitution are $\sigma_p > 1$. Total measure of the world economy is normalized to unity, with sizes of the domestic and foreign economies having measures n and $(1-n)$, respectively.

Households own firms in the domestic economy and thus are recipients of profits earned by banks and capital producing firms net of new capital infusion into banks, Π_t^e. They consume home and foreign goods bundled together by retail firms C_t^e. The households purchase a complete set of Arrow-Debreu securities B_t^e at the rate $R_t^* \Psi_t$[3]. The foreign interest rate faced by domestic agents is assumed to be increasing in the aggregate level of foreign debt, hence $\Psi_t = \frac{\Psi}{2}(\exp(B_t^e - B^e) - 1)^2$, where Ψ_t is country-specific interest rate premium and Ψ is a constant parameter. Other sources of income for the representative household are wages W_t^e, and new borrowing net of interest payments. The representative household's budget constraint in period t can, therefore, be written as follows:

$$P_t^e C_t^e + B_{t-1}^e R_{t-1}^* \Psi_t S_t = W_t^e H_t^e + B_t^e S_t + \Pi_t^e, \tag{4.2}$$

where P_t^e denotes the price of consumption in the EE and S_t denotes the nominal exchange rate in period t, defined as the price of foreign currency in terms of domestic currency.

The representative household chooses the paths for $\{C_t^e, H_t^e, B_t^e\}_{t=0}^{\infty}$ in order to maximize its expected lifetime utility in (4.1) subject to the budget constraint in (4.2).

[3]This specification is introduced mainly for technical purposes to induce stationarity, as is common in small open economy models with incomplete asset markets, as proposed by Schmitt-Grohé and Uribe (2003).

4.2.1.2 Retail firms

There are three types of firms in the model: retail firms, intermediate goods firms, and capital producing firms.

Retail firms purchase intermediate goods at price $P_{e,t}$ relative to the domestic consumption price index P_t^e, and produce the non-tradable final good using the technology:

$$Y_t^e = (\nu_e^{\frac{1}{\eta}} Y_{e,t}^{1-\frac{1}{\eta}} + (1-\nu_e)^{\frac{1}{\eta}} Y_{c,t}^{1-\frac{1}{\eta}})^{\frac{\eta}{\eta-1}}, \tag{4.3}$$

where $\nu_e > 0$ measures the degree of home bias in domestic demand, $-\eta > 0$ is the trade of elasticity, and Y_{jt} is the country $j = \{e, c\}$ production of the traded intermediate good.

The EE price level consistent with the constant elasticity of substitution (CES) function shown in technology equation (4.3) is thus implicitly defined by the following CES aggregator

$$1 = (\nu_e P_{e,t}^{1-\eta} + (1-\nu_e)(RER_t P_{c,t})^{1-\eta})^{\frac{1}{1-\eta}}. \tag{4.4}$$

where RER_t is the price of the CC consumption basket in terms of domestic consumption basket, and $P_{c,t}$ is the CC producers price relative to the CC consumption-price index P_t^c.

4.2.1.3 Intermediate goods producers

Each intermediate goods production firm combines labour H_t^e and capital K_t^e to produce a differentiated good indexed by $j \in [0, 1]$ using a Cobb-Douglas production function:

$$Y_{e,t} = A_{e,t}(\xi_t K_{t-1}^e)^\alpha {H_t}^{e(1-\alpha)}, \tag{4.5}$$

where $A_{e,t}$ denotes total factor productivity in the intermediate goods sector in EE, K_t^e denotes capital provided by the entrepreneur, as is explored in the following subsection, and H_t^e is the composite labor input. Given that the price of each input is taken as given, intermediate goods producers minimize their costs subject to (4.5). The production function is subject to the AR(1) total factor productivity shocks ($A_{e,t}$) and the AR(1) capital-quality shock (ξ_t).

Intermediate goods producers have some market power and they segment domestic and foreign markets with local currency pricing, where $P_{H,t}(j)$ and $P_{X,t}(j)$ denote price in domestic market (in domestic currency) and price in the foreign market (in foreign currency).

To purchase capital the entrepreneurs obtain funds by selling securities $Z_t^e = K_t^e$ to domestic banks, the payoff which is fully indexed to the marginal return on capital, defined as

$$r_t^e \equiv MC_t^e \alpha A_t^e H_t^{e(1-\alpha)} \frac{K_t^{e(\alpha-1)}}{\xi_t^e}, \tag{4.6}$$

where MC_t^e is the real marginal cost of production in terms of the domestic consumption-price index P_t^e.

The model assumes a Calvo pricing formulation which implies the following specification for the producer price index where π_{et}^{ppi}denotes the rate of inflation, as follows:

$$\Pi_{e,t}^* = \frac{\sigma_p}{\sigma_p - 1} \frac{\Pi_{e,t}^1}{\Pi_{e,t}^2}, \tag{4.7}$$

$$\Pi_{e,t}^1 = Y_{e,t} MC_t^e + \mathbb{E}_t[\phi \Lambda_{t,t+1}^e \pi_{et}^{ppi(\sigma_p)} \Pi_{e,t+1}^1], \tag{4.8}$$

$$\Pi_{e,t}^2 = Y_{e,t} P_{e,t} + \mathbb{E}_t[\phi \Lambda_{t,t+1}^e \pi_{et}^{ppi(\sigma_p - 1)} \Pi_{e,t+1}^2], \tag{4.9}$$

$$1 = \phi \pi_{et}^{ppi,(\sigma_p - 1)} + (1-\phi) \Pi_{e,t}^{*,(1-\sigma_p)}; \tag{4.10}$$

where $\Pi_{e,t}^*$ denotes the inflation rate of newly adjusted goods prices, and $\frac{\sigma_p}{\sigma_p - 1}$ represents the optimal static markup of price over marginal cost.

4.2.1.4 Capital producing firms

A set of competitive firms use newly purchased investment goods as input, I_t^e and combine it with old capital K_t^e, depreciated at rate $1-(1-\delta)\xi_t$ (where $\delta \in (0,1)$ is the rate of depreciation), to produce unfinished capital goods, subject to adjustment costs function,

$$I_t^e + I_t^e \frac{\varsigma}{2} \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right)^2.$$

Capital producers buy back the old capital from banks at price Q_t^e and produce new capital from the final good in the EE subject to the adjustment cost function. Consequently, the aggregate stock of capital evolves according to the following law of motion

$$K_t^e = I_t^e + (1-\delta)\xi_t K_{t-1}^e. \tag{4.11}$$

The optimality condition for the unfinished capital producing firms with respect to the choice of I_t^e yields the following nominal price of a unit of capital Q_t^e:

$$Q_t^e = 1 + \frac{\varsigma}{2}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right)^2 + \varsigma\frac{I_t^e}{I_{t-1}^e}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right) - \Lambda_{t+1}^e\varsigma\left(\frac{I_{t+1}^e}{I_t^e}\right)^2\left(\frac{I_{t+1}^e}{I_t^e} - 1\right). \tag{4.12}$$

where ς denotes the adjustment cost of investment.

4.2.1.5 Monetary Policy

We adopt a standard formulation of monetary policy which adjusts domestic policy rate to meet the targets of stable inflation and GDP growth. Hence the policy rate evolves according to:

$$R_t^e = R_{t-1}^{e(\lambda_r)}\left(R^e\left(\frac{\pi_t^e}{\pi_{obj}}\right)^{\lambda_p}(Y_t^e/Y^e)^{\lambda_y}\right)^{(1-\lambda_r)}\rho_t^{MP,e}, \tag{4.13}$$

where Y^e and R^e denote the steady-state level of output and interest rate, and $\rho_t^{MP,e}$ is a monetary policy shock.

4.2.1.6 EE Banks

The specification of the banking operation is motivated by the concept of imperfect financial intermediation, along the lines of Gertler and Karadi (2011). Bank i begins with some bequeathed net worth $N_{i,t}^e$ from the households to start the bank's operation. In addition to net worth transfer from the household, EE banks borrow an amount $V_{i,t}^e$ in units of the domestic consumption bundle from the global bank at the real interest rate R_{bt}. At the end of t, bank i that survives decides how much to invest in capital $K_{t,i}^e$ at price Q_t^e.

In the beginning of operation, EE bank $i's$ balance sheet is given by

$$Q_{t,i}^{e}K_{t,i}^{e}=N_{i,t}^{e}+RER_{t}V_{it}^{e}, \tag{4.14}$$

where $RER_t = \frac{S_t P_t^c}{P_t^e}$ is the real exchange rate, as defined earlier.

Bank $i's$ net worth is the difference between the return on previous period's investment and its debt payments to the global bank:

$$N_{i,t}^{e}=R_{k,t}^{e}Q_{t-1}^{e}K_{t,i}^{e}-RER_{t}R_{b,t-1}V_{i,t-1}^{e},$$

where $R_{k,t}^{e}$ is the gross return on capital defined as

$$R_{k,t}^{e}\equiv\xi_{t}\frac{r_{t}^{e}+(1-\delta)Q_{t}^{e}}{Q_{t-1}^{e}}.$$

where r_t^e is the marginal return on capital, as specified in Equation (4.6).

The imperfect financial intermediation introduces limited enforceability problem, as in Gertler and Karadi (2011). *Ex ante*, banks have an incentive to abscond from the operation and revert back to their household unit with probability $1-\theta$, and a probability θ to continue the bank's operation, before the investment is made. Consequently, conditional on their net worth, bank leverage must be limited by a constraint that ensures there is no incentive to abscond.

Since banks have an incentive to abscond with the proceeds of the part of the loan and their existing net worth, the borrowing from the global banks have to be structured such that the value of absconding does not exceed the value of EE bank's investment. If this is not the case, bankers would prefer to 'default'. This is the incentive compatibility constraint (ICC) condition. The fraction of EE banks' net worth that can be absconded is defined as κ^e, a parameter that represents the degree of the agency problem. Hence denoting the bank's value function by $J_{i,t}^e$, the incentive compatibility constraint requires that

$$J_{i,t}^{e}\geq\kappa^{e}Q_{i,t}^{e}K_{i,t+1}^{e}. \tag{4.15}$$

The parameter governing the degree of agency problem in the EE banks κ_e is assumed to represent the scale of financial frictions in the EE banking sector which serves as a proxy for the stage of financial sector development of the economy. In this sense, an economy with higher degree of agency problem is assumed to represent an economy with less developed banking system.

The problem of EE bank i at time t is to maximize the value, as follows:

$$\max_{[K^e_{i,t+1}, V^e_{i,t}]} J^e_{i,t} = E_t \Lambda^e_{t+1} [(1-\theta)(R^e_{k,t+1} Q^e_t K^e_{t+1,i} - RER_{t+1} R_{b,t} V^e_t) + \theta J^e_{i,t}$$

subject to balance sheet constraint (Equation 4.14) and the incentive compatibility constrain (Equation 4.15).

The evolution of net worth averaged across all EE banks, taking into account that banks exit with probability $1-\theta$, and the new banks receive infusions of cash from households at rate δ_T times the existing value of capital, can be written as:

$$N^e_{t+1} = \theta \left(\left(R^e_{k,t+1} - \frac{RER_{t+1}}{RER_t} R_{b,t} \right) Q^e_t K^e_t + \frac{RER_{t+1}}{RER_t} R_{b,t} N^e_t \right) + \delta_T Q^e_t K^e_{t-1.} \quad (4.16)$$

The first term on the right hand side denotes the increase in the net worth of the surviving banks given the return on investment, while the second term shows the value of 'start-up' from household to newly established banks.

4.2.1.7 Macroprudential policies (MaP)

In this section we introduce MaP rules, defined as a countercyclical time-varying tax/subsidy scheme, along the lines of Gertler et al. (2012) and Levine and Lima (2015). The countercyclical tax/subsidy is levied on the EE banks' net worth directly. The timing of the macroprudential regulation scheme is as follows. In period t, tax or subsidy rates τ^e_t are set to be paid or received on the value of end-of-period t (or beginning of period $t+1$). The net worth of the banks then evolves according to:

$$N^e_{t+1} = \theta \left(R^e_{k,t+1} Q^e_t K^e_t - \frac{RER_{t+1}}{RER_t} R_{b,t} Q^e_t K^e_t - \tau^e_t Q^e_t K^e_t + \frac{RER_{t+1}}{RER_t} R_{b,t} N^e_t \right) + \delta_T Q^e_t K^e_{t-1.} \quad (4.17)$$

where δ_T denotes the transfer rate to new bankers.

Equation (4.17) suggests that the net worth is equal to the gross returns minus gross costs of cross-border borrowing from the global bank, net of subsidies (plus taxes) carried over from the previous period, plus infusions of cash from households.

The dynamics of the tax/subsidy is affected by the dynamics of a financial indicator on which the tax/subsidy is calculated. We consider four different financial indicators and hence four types of MaP measures in our experiment; bank's leverage ratio (LR); loan-to-GDP (LG); credit growth (CG) and foreign borrowing (FB). These measures closely correspond to the MaP measures widely adopted by EE in practice, particularly since 2009 (see, for example, Lim et al. (2011)). Macroprudential tools with respect to bank's leverage ratio in general fall under the classification of capital-based tools, whereas loan-to-GDP ratio and credit growth are categorized as asset-side tools/loan restrictions. Finally, macroprudential tools with respect to foreign borrowing are similar to restrictions on capital flows and affect banks' liabilities side.

The specification of the four financial indicators can be characterized as follows:

$$\left(\frac{1+\tau_t^e}{1+\tau^e}\right) = \left(\frac{1+\tau_{t-1}^e}{1+\tau^e}\right)^{\rho_\tau} \left(\frac{X_t}{X}\right)^{\alpha_X}, \tag{4.18}$$

where X_t represents either of: bank's leverage ratio $lev_t^e = \frac{Q_t^e K_t^e}{N_t^e}$, the loan-to-GDP ratio $\frac{Q_t^e K_t^e}{Y_t^e}$, credit growth $cg_t = \frac{Q_t^e K_t^e}{Q_{t-1}^e K_{t-1}^e}$, and the cross-border bank borrowing V_t^e at time t, whereas X denotes the respective steady-state values.

In Equation (4.18), ρ_τ, measures the degree of persistence of macroprudential instrument, α_X, denotes the responsiveness of the MaP measure to the deviation of the relevant indicator from its steady-state value. When the financial indicator in question (either of total credit, loan-to-GDP ratio, credit growth, and foreign borrowing) is high relative to its steady-state, taxes on banks are raised, decreasing their net worth and ability to extend loans to non-financial sector, and hence dampening the business cycle. We set the degree of response of the MaP, α_{lev}, α_{QKY}, α_{cg}, $\alpha_V > 0$ to ensure a counter-cyclical MaP rule. The type of macroprudential policy implemented is mutually exclusive, i.e. we consider the effect of each MaP measure on the economy one at a time. For example, when the leverage ratio is the basis of the MaP, we set $\alpha_{lev} > 0$, $\alpha_{QKY} = \alpha_{cg} = \alpha_V = 0$.

4.2.2 The Advanced Economy (AE)

4.2.2.1 Model structure

The AE's households and production functions are identical to those of the EE, except that the population size of the AE is larger than EE and thus introducing home bias. As with the EE, the AE economy also imports a fraction of EE's production to make the final goods composition for the AE.

The banking sector of the AE is slightly different from that of EE banks, as AE's financial intermediaries (the global bank) receive deposits from AE household and guarantees them the risk-free interest rate in return, whereas EE banks only receive deposits from AE banks and not from domestic households. Deposits together with the bank's own net worth (retained earnings) makes up the global bank's value, which is then invested in the EE bank as well as the AE technology. Given that the specification for households and firms of the AE is similar to EE, other details are presented in the Appendix.

4.2.2.2 AE (global) banks

The global banks have a similar incentive compatibility constraint as faced by the EE banks. The global bank j has a balance sheet constraint given by

$$RER_t^{-1} V_{j,t}^e + Q_t^c K_{j,t}^c = N_{j,t}^c + B_t^c, \tag{4.19}$$

where superscript c (centre) denotes variables for AE, V_{jt}^e is the investment in the EE bank, and $Q_t^c K_{j,t}^c$ is the investment in the CC capital stock. $N_{j,t}^c$ is the global banks' net worth (the retained earnings), and B_t^c are deposits the global banks received from AE's households. All variables are denominated in real terms (in terms of the CC CPI).

The global banks' value maximization problem can then be written as:

$$J_{jt}^c = E_t \max_{[K_{j,t+1}^c, V_{jt}^e, B_{jt}^c]} \Lambda_{t+1}^c [(1-\theta)(R_{k,t+1}^c Q_t^c K_{j,t}^c + R_{b,t} V_{jt}^e - R_t^* B_t^c) + \theta J_{j,t+1}^c], \tag{4.20}$$

where Λ_{t+1}^c is the stochastic discount factor in the core country, $R_{b,t}$ is the real interest rate received by global banks from investing in the EE banks, and R_t^* is the risk-free interest rate paid to CC households.

As with the EE banks, the global banks also face the no-absconding constraint:

$$J_{jt} \geq \kappa_t^c (RER_t^{-1} V_{jt}^e + Q_t^c K_{j,t}^c), \tag{4.21}$$

where κ^c is the parameter that measures the degree of agency problem in the global banks, similar to κ^e in the EE banks.

As in the EE banks, we can describe the dynamics of the global banking system's net worth by assuming that all global banks are identical, and then averaging across surviving banks, and including the net worth provided by the core country's households as 'start-up' for the new banks. This results in the following law of motion for the global banking system:

$$N_{t+1}^c = \theta((R_{k,t+1}^c - R_t^*)Q_t^c K_t^c + (R_{b,t} - R_t^*)V_t^e + R_t^* N_t^c) + \delta_T Q_{t+1}^c K_{t-1}^c, \tag{4.22}$$

The first order conditions for the global banks maximization problem is presented in the Appendix. Again, the details of the households and firms optimization problem of the AE are identical to those of the EE. Also the AE implements a standard Taylor rule in the making of monetary policy, similar to the EE. However, in order to focus on the effectiveness of MaP measures in the EE, we maintain that the AE does not implement any MaP.

4.3 Parameterization

For the majority of parameters governing preferences and technology we follow the calibration in the existing work on core-periphery models featuring international banks, such as Banerjee et al. (2016) and Agénor et al. (2017), as outlined in Table 4.1. We calibrate our banking parameters to match the World Bank data of average interest rate spread and leverage ratio during 2005-2016.

Time is measured in quarters. For the household sector, we set the discount factor β at 0.99, implying a riskless annual return of approximately 4 per cent in the steady-state. The inverse of the Frisch elasticity of labour supply is set to 0.276, implying elasticity of labour supply $\frac{1}{1+\psi}$ of 0.8. Both parameter values are in line with Banerjee et al. (2016). The risk aversion parameter σ is set at 1, implying a standard separable utility function with logarithmic consumption, as in Agénor et al. (2017).

The parameters of the wholesale firms are standard; the capital share in production α is taken to be 0.3, implying the share of hours in production $(1-\alpha) = 0.7$. The depreciation rate is set $\delta = 0.025$, as is widely used in the existing literature. The parameter in the adjustment cost technology of the capital producing firms ζ is 2, as adopted by Agénor et al. (2017).

Following Banerjee et al. (2016), the Calvo parameter for the retail firms ϕ is taken to be 0.8, corresponding to a probability of changing prices in a quarter $(1-\phi)$ of 0.2. The elasticity of substitution σ_p is set at 6, implying steady-state markup of price over marginal cost $\frac{\sigma_p}{\sigma_p-1} = 6/5$.

We follow Agénor et al. (2017) for the parameters concerning the retail sector. The degree of home bias in domestic demand, ν_e and ν_c, are set at 0.80 and 0.97, respectively. The Armington trade elasticity of substitution between home and foreign goods (η) is 1.5, firmly within the range of the empirical estimates [-0.9 – 3.54](see, for example, Saito (2004)).

Three parameters governing the financial sector (i.e. θ, κ^e, and δ_T) are set as follows: the parameters of incentive compatibility constraint $\kappa^e = 0.3$ together with the transfer rate to new bankers $\delta_T = 0.004$ are set to meet the target values of the spread earned by banks on their assets (100 bps) and the leverage ratio to be around 8.[4] Following Agénor et al. (2017), the survival probability of banks θ is set to 0.9.

Finally, the coefficients of the Taylor rule and the macroprudential policy rules are also presented in Table 4.1. The parameters concerning the monetary policy are in line with Banerjee et al. (2016). The Taylor rule persistence parameter λ_r is set to be 0.85, whereas the Taylor rule parameter with regard to inflation λ_p and growth λ_y are 1.2 and 0.2, respectively. To make the three macroprudential experiments comparable, we assume that the coefficients of the macroprudential policy rule under each macroprudential instrument are the same.

[4]The World Bank data shows that the average of the leverage ratio across the world during 2005-2016 is around 10. The ratio for the US is 8.37, quite close to those of big emerging economies like Turkey and Indonesia, which are 8.62 and 8.03, respectively.

4.4 Policy experiments

We first look at the effect of the Fed lift-off on the EE's financial and macroeconomic outcomes in the benchmark case under full capital mobility (full financial integration) and a flexible exchange rate. This is applied to our model framework by imposing a 0.5% shock in the monetary policy Equation (4.13). We then examine how effective the benchmark monetary/MaP mix is in reducing domestic macroeconomic and financial volatility following the foreign interest rate hike in the benchmark.

In our second set of experiments, we relax the capital mobility assumption by introducing a barrier to capital mobility in the banking sector. In particular, we ask whether a lower capital mobility alters the effect of foreign interest rate rise on domestic stability. We then investigate how macroprudential policy effectiveness is changed under this condition.

In the third set of experiments, we explore the case where the EE forgoes its monetary policy independence and implement a fixed exchange rate regime. We then evaluate the implication of a fixed exchange rate regime on the effectiveness of the macroprudential policy.

In formalizing the restrictions to capital mobility, we follow Agénor and Jia (2017) by introducing a premium that induces a wedge between the effective cross-border lending rate and the unadjusted cross-border lending rate:

$$R^e_{b,t} = R_{b,t}(1 + \Delta_t), \tag{4.23}$$

where $R^e_{b,t}$ is the effective cross-border lending rate, $R_{b,t}$ represents the unadjusted cross-border lending rate, and Δ_t is the premium that is linked to the scale of financial integration, $F^e \geq 0$; and the level of cross-border bank lending, V^e_t:

$$\Delta_t = F^e V^e_t. \tag{4.24}$$

where $F^e = 0$ corresponds to full financial integration - the benchmark case.

The relationship depicted by Equation (4.23) and (4.24) implies that, everything else constant, a greater financial integration reduces the premium, Δ_t, leading to the realized lending rate that is not too different from the unadjusted (optimal) rate. The premium depends positively on the level of cross-border lending, which implies that as borrowing increases, so does the associated risks, and hence the required risk premium. In our experiments, we set $F^e = 0$ for full integration, and $F^e = 0.005$ for the case of lower financial integration.

In studying the impact of foreign interest rate hikes on the domestic (EE) economy, in addition to the impulse responses, we also calculate volatilities of each variable as a deviation from the relevant steady-state level in each policy regime. This allows us to assess numerically the performance of each macroprudential instrument as defence against the Fed-lift off, separately.

Our volatility measure is based on empirical moments obtained from 2000 simulations in each scenario. The effect is averaged throughout the total periods of shocks which we consider until 30 periods. For each simulation, the volatility measure of any variable i is defined as follows:

$$volat_i^T = 100 \times \frac{1}{Y_i^*} \sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_{i,t} - Y_i^*)^2} \tag{4.25}$$

where $volat_i^T$ represents the volatility of variable i, T is the time since the onset of the shock, $Y_{i,t}$ represents the value of variable i at time t, whereas Y_i^* is the steady-state value of variable i.

4.5 Fed lift-off and the emerging economy

In our experiments, policy-makers in both countries implement monetary policy through the use of standard Taylor Rule. To evaluate how the Fed lift-off affects the domestic economy, in this sub-section, we abstain from any use of MaP.

4.5.1 The impact of foreign interest rates on emerging economy

We start by looking at the impact of the rise in the foreign interest rate on the foreign economy, as depicted in Figure 4.1. As is clear in Figure 4.1, the rate rise in the CC reduces aggregate demand on impact in the centre economy. The increase in the lending rate is higher than the increase in the deposit/saving rate, hence the interest rate spread widens, curtailing investment demand and thus reducing asset prices. As a result, aggregate credit drops on impact and continues to contract until about ten periods (2.5 quarters). As the credit to the non-financial sector falls, bank's profitability is reduced and so is the net worth. This pushes up bank leverage (ratio of aggregate credit to bank's net worth) on impact which then falls gradually. As business and consumption activity slows down, GDP in the centre economy drops on impact, but gradually returns to the steady-state.

The response of the domestic economy to the rise in foreign interest rate is depicted in Figure 4.2. The cross-border transmission of shock from the AE to the EE in this model works through the cross-border bank lending from the global bank to the EE bank, in addition to the international risk-sharing activity by the EE households who buy the internationally traded AE bond. To the extent that the profit maximising global bank determines cross-border lending rate and the rate at which it is provided, a monetary contraction in the AE impacts the financial and macroeconomic outcomes in the EE.

The higher lending rate in the AE together with the slowing down of the economy causes a drop in the cross-border bank lending from the global bank to the EE bank. Because of this surge of capital outflows, the net foreign asset (the net amount of EE lending abroad minus EE foreign borrowing) increases on impact, leading to real exchange rate depreciation in the EE. As a result, EE inflation overshoots although this is quite short-lived - about a year after the shock. The spikes in inflation prompt the monetary authority to raise domestic interest rate to contain the rise in inflation in the long-term. The monetary contraction in the AE does not only increase the policy rate in the EE, but also the marginal rate of capital (or the cost of investment in the non-financial sector), leading to a fall in investment and aggregate credit.

The real exchange rate depreciation improves the EE's terms of trade, increasing its exports, raising GDP increases and hence consumption, around one year following the foreign interest rate hike.

4.5.2 Macroprudential policy (MaP)

Now we turn to assessing the effectiveness of different MaP measures as defence against the foreign interest rate rise.

Figure 4.3 displays the response of the domestic economy under four separate MaP regimes and Table 4.2 presents the associated volatilities under high capital mobility and a flexible exchange rate regime (the benchmark case). As set out in Equation (4.18), we adopt a macroprudential rule that reacts to four financial conditions; leverage ratio (total credit/self-funded net worth); loan-to-GDP ratio (total credit/GDP); credit growth; and foreign bank borrowing. The MaP experiment for each instrument is mutually exclusive, by examining one measure at a time.

Figure 4.3 reveals that financial variables that are most affected by the MaP are net foreign assets, cross-border borrowing, bank leverage, and the aggregate credit. The effect of MaP on these variables is then transmitted onto outcomes such as investment, consumption, and GDP.

In order to take a closer look at the effect of each MaP, Table 4.2 presents volatilities of selected key variables following the foreign interest rate increase. For ease of comparison, the right panel presents relative volatilities, calculated as the volatilities under each MaP rule relative to the volatilities under no MaP:

$$relvol_i^{MaP} = \frac{volat_i^{MaP} - volat_i^{noMaP}}{volat_i^{noMaP}} \tag{4.26}$$

where $relvol_i^{MaP}$ represents the relative volatilities, $volat_i^{MaP}$ represents volatilities of variable i under MaP, whereas $volat_i^{noMaP}$ refers to volatilities under no MaP implementation. Volatilities are calculated for a set of macroeconomic, financial and policy variables, as listed in the first column in Table 4.2.

Negative values (in bold numbers) of a particular variable indicate that, following the foreign interest rate shock, the variable in question is less volatile relative to the benchmark case of no MaP. Hence, a negative value denotes that a particular MaP is effective in reducing fluctuations. In Table 4.2 all values are calculated for the cases of full financial integration and a flexible exchange rate regime.

In analysing the effectiveness of macroprudential instruments in reducing volatilities, we firstly focus on the ability of the different type of macroprudential policies to reduce the volatility of *credit growth* as it is mostly the objective of MaP implementation. The results reveal that, almost all specific MaP measures are effective in reducing the fluctuation of the credit growth except when MaP is based on the leverage ratio (LR). This is due to the fact that leverage ratio is determined by banks' net worth which is highly affected by the policy, and therefore very volatile.

If the aim of MaP is to reduce volatilities in asset prices, the policy on leverage ratio (LR) and foreign borrowing (FB) does the best job. If the stability of foreign capital inflows is the main concern, a policy that is directed towards credit growth (CG) is better, as the foreign banking borrowing is more effectively stabilized under this MaP instrument.

Comparing across different MaP instruments, it is clear that MaP that is tied to cross-border bank borrowing (FB) performs better than the other macroprudential policies followed by the instrument that targets loan-to-GDP ratio (LG), with the former reducing fluctuations in almost all key variables, except investment and interestingly, foreign bank borrowing. The failure to stabilize FB should not come as a surprise given that the foreign borrowing is the major channel of external contagion to the domestic conditions in EE in our framework, making the volatilities of this variable difficult to curb, hence the erratic response of foreign borrowing to the shock in the foreign interest rate.

4.6 The effects of barrier to capital mobility

4.6.1 The impact of the Fed lift-off under lower financial integration

Our analysis in the previous section maintained that there was high financial integration between the EE and the centre economy, with clear implications for the scale of cross-border lending and the prevailing interest rate. An issue worth exploring is how the domestic economy's response to the foreign interest rate rise is impacted upon under a lower degree of financial integration.

Figure 4.4 depicts the response of the domestic economy to the foreign interest rate rise under two levels of financial integration; high as in the benchmark versus low. The straight (dashed) line represents the case of full (low) financial integration. As earlier, there is no MaP in the benchmark.

An EE with a low level of financial integration experiences a smaller drop in borrowing from the global bank. The smaller reduction in the cross-border lending, in turn, reduces real exchange rate depreciation. Since the foreign lending the global bank extends to local EE bank (the only source of EEs fund, in addition to own net worth) drops by less under low financial integration, the unfavourable impact on the domestic economy is smaller. In general, a foreign monetary policy rate shock under low financial integration reduces the GDP by less in general, and reduces consumption by more in the short run but then increases by more in the long run.

There is no clear difference on inflation under high versus low financial integration.

Table 4.3 lists the ranking of the steady-state values under two different levels of financial integration. It turns out that, even though the reduction of foreign borrowing from the global bank is smaller under restricted capital mobility, in the long run greater financial integration delivers greater benefits. In particular, financial openness allows the global bank to lend more to the financially integrated EE bank at a lower rate. With greater cross-border lending, the cost of investment (return on capital) is lower, reducing the need for the local banks to build up more self-funding net worth. As a result, greater financial integration yields more efficient provision of capital, and hence more investment, and output. This finding supports previous studies' result that capital mobility is beneficial for economic growth through its effect on the capital market deepening supporting finance investment projects, particularly in emerging economies (Levine, 2005; Haldane, 2011).

Table 4.4 presents the volatilities of key variables arising from the foreign interest rate shock, as calculated by Equation (4.25). The first two columns represent the percentage deviation from the steady-state, our measurement of volatilities. Column four presents volatilities of the variables under low financial integration relative to the benchmark where negative numbers (marked by bold numbers) correspond to lower volatilities as compared with full integration, and *vice versa* for the positive numbers.

It is evident from Table 4.4 that out of the 13 variables considered, 8 exhibit increased volatilities under low financial integration whereas 5 others are more stable following monetary policy contraction in the centre economy. The magnitude of the volatilities confirm our earlier observation from the impulse responses; foreign bank borrowing and real exchange rate are more stable under low financial integration (with imperfect capital mobility). The table also shows that all financial related variables -asset price, leverage ratio, spread, and net worth of banks- are more unstable with less integration. Two real variables -GDP and investment- also become more unstable after the shock. Nevertheless, this is not a negative outcome. In fact, the more volatilities in the GDP and investment level under low financial integration are due to a higher increase in the two variables that materialize around ten quarter after the shock.

Overall, in the face of a foreign interest rate rise, an EE with impediments in capital mobility is better off as capital inflows drop less and the aggregate credit conditions are less unfavourably affected. This leads to higher level of macroeconomic variables like the GDP and consumption. Nevertheless, fluctuations in financial variables such as asset prices, the leverage ratio, spread, and net worth of banks are greater with less capital mobility. Furthermore, in the long run, impediments to capital mobility hold back the EE from reaping the benefits of financial integration such as lower cross-border borrowing rate and greater capital inflows in the banking sector.

4.6.2 Financial integration and the effectiveness of MaP

We now turn to the role of financial integration on the effectiveness of different MaP scenarios. Table 4.5 present the impact of a rise in the foreign interest rate on the outcomes in the domestic economy under low financial integration and a flexible exchange rate regime. When we consider restrictions on capital mobility, we find that the effectiveness of MaP improves markedly. This is particularly the case for MaP that targets the foreign banking borrowing (FB) and the loan-to-GDP ratio (LG), reducing the volatility of nearly all variables significantly following the foreign rate shock relative to no MaP.

With low capital mobility, MaP is effective in significantly reducing fluctuations in almost all *financial variables* - credit growth, asset price, leverage ratio, the spread between borrowing and lending rate, and the net worth of banks - regardless of the MaP instrument chosen. Existing empirical work also points in the same direction. For example, in a recent paper, Cerutti et al. (2017) finds that the macroprudential policies are less effective in financially more open economies. Schoenmaker (2011) also points to the possibility that policies that serve domestic purposes may create domestic instability when the domestic economy is financially integrated to the rest of the world. This is widely referred to as the *financial trilemma* which refers to the notion that (1) financial stability; (2) financial integration; and (3) national financial policies cannot be achieved altogether. Only two of three conditions can be materialized, but not all three; one has to give. Consistently, in our framework, national macroprudential policy leads to greater financial stability once financial integration is reduced.

The effect of MaP on macroeconomic variables depends on the individual MaP measure. Improvements in stability are significant under the loan-to-GDP ratio (LG) and foreign borrowing (FB) instruments, but not under the credit growth (CG) and leverage ratio (LR) instruments. It is also surprising to see that foreign related variables (i.e. real exchange rate and foreign banking borrowing) are more volatile when each MaP instrument is implemented in an EE with imperfect capital mobility. This may suggest that MaP introduces more distractions in the relative rate of returns between the AE and the less financially integrated EE. Put differently, MaP is effective in minimizing fluctuations in the financial variables at the cost of more fluctuations in the real exchange rate and foreign flows.

4.7 Does the choice of the exchange rate regime matter?

4.7.1 The impact of Fed lift-off with fixed exchange rate regime

It is well-known that emerging market countries are more likely to adopt fixed exchange rate regimes, largely due to substantial foreign currency denominated debt - liability dollarization (see, for example, Hausmann et al. (2001)). A key question arising from our analysis is whether the choice of exchange rate regime impacts upon the effectiveness of the four MaP measures as defence against the foreign interest rate shock.

Figure 4.5 depicts the outcomes in the domestic (EE) economy in the face of contraction of monetary policy in the CC under both fixed and flexible exchange rate regimes. The black line represents the benchmark case of flexible exchange rate regime, whereas the dashed line represents a fixed exchange rate economy.

Following a foreign interest rate hike, the domestic economy experiences a greater drop in cross-border banking flows under a fixed exchange rate regime. The change in interest rate differential between EE and AE following the foreign interest rate rise induces capital outflows in the banking sector. When the exchange rate is flexible, capital outflows bring about the depreciation of the domestic currency, slowing down the outflows where the flexibility in the exchange rate performs the role of shock absorbing.

The impulse responses reveal that the real exchange rate is more stable with the fixed exchange rate regime, as expected. Some dynamics still occur in the real exchange rate which reflects the relative price movements between the EE and AE. To curb large capital outflows, EE's monetary authority increases policy rate by a greater margin under the fixed exchange rate regime.

The greater drop in the foreign lending brings about more reduction in aggregate credit to the real sector. Local bank's profitability is also affected more negatively as net worth drops more. As a result, EE's investment falls more on impact and thus the national output contracts to a greater extent. This condition affects consumption level negatively most noticeably in the short run.

Table 4.4 compares the volatilities of variables in EE which adopts the hard peg with the benchmark case of a flexible regime. Column five represents the volatilities of the variables under the fixed exchange rate EE relative to the flexible exchange rate benchmark, confirming our observation from the impulse responses in Figure 4.5. An emerging economy which adopts a fixed exchange rate regime is worse off in the face of an increase in foreign interest rate than an EE with flexible exchange rate regime. In particular, all key variables exhibit greater fluctuations under the fixed exchange rate.

4.7.2 Exchange rate regime and the effectiveness of MaP

Table 4.6 compares the relative effectiveness of different MaP measures in fluctuations following the positive foreign interest rate shock under a fixed exchange rate regime. The first result that emerges is that, MaP provides better defence against the foreign interest rate shock under the fixed exchange rate regime, with the exception of the MaP targeting the leverage ratio (LR).

In a hard peg regime, the MaP that use the foreign bank borrowing (FB) as instrument appears to be the best as almost all variables are less volatile under this MaP implementation, especially the financial variables i.e. the credit growth, asset price, leverage ratio, interest rate spread, and bank's net worth. This is followed by the MaP that is based on the loan-to-GDP ratio (LG) as the instrument. This MaP is able to reduce all key macroeconomic variables i.e. the GDP, consumption, employment, and investment.

With fixed exchange rate regime, MaP is effective in curbing fluctuations in the credit growth, again with the exception of the leverage ratio (LR). As in the real world, the implementation of MaP is primarily to reduce the credit growth, an EE adopting fixed exchange rate regime may consider implementing macroprudential policy with the loan-to-GDP ratio (LG), credit growth (CG), and foreign borrowing (FB) as instruments. Some other countries mainly focus on curbing the asset price bubbles, then leverage ratio (LR) and FB type of macroprudential policy can be considered. The two key monetary variables - inflation and interest rates, and the real exchange rate are also more stable with MaP implementation. Nevertheless, MaP with the credit growth (CG) instrument appears to increase volatility in key financial variables, i.e. asset price, leverage ratio, spread, and net worth.

4.8 Extension

4.8.1 The role of financial development

Our analyses in the previous two sections focussed on the role of financial integration and the exchange rate regime on our benchmark results. In this section, we repeat the same exercise for the role of the level of financial development. We take the degree of financial frictions to represent the financial system development in the EE, where low financial frictions correspond to greater financial development. As earlier, in the benchmark case, no MaP is implemented. In our framework, the different scales of financial frictions taken to arise from the different degrees of the agency problem facing local banks, as explained earlier. Since the bank has an incentive to abscond with the proceeds of the loan and its existing net worth, the amount of global bank lending to the EE bank must be defined such that the bank's continuation value from investing exceeds its absconding value. Thus, the bank faces the incentive compatibility constraint:

$$J_t^e \geq \kappa^e Q_t^e K_t^e \tag{4.27}$$

where J_t^e is the bank's value function, κ^e is the degree of agency problem, Q_t^e is the price of capital, and K_t^e is the capital investment by the EE bank. We set $\kappa^e = 0.3$ for the benchmark case of low financial frictions, and $\kappa^e = 0.7$ for the high financial frictions case.

An economy with a greater agency problem (i.e. higher κ^e) is the one facing higher financial frictions. In such an economy, it is optimal for the global bank to lend less to the EE bank given the higher possibility of lending to be absconded. Thus in the steady-state, an economy with high financial frictions receives less foreign cross-border flows compared to the one with lower financial frictions.

In general, an economy with greater financial frictions is affected less by the increase in the policy rate in the CC. The reasons for this are two-fold. Firstly, this is due to the fact that the global bank is more constrained to lend to EE bank, reducing its impact in proportion to total lending. Secondly, the link between the domestic lending and the international interest rate is weaker. Hence, an increase in foreign rate increases the spread between the lending and the deposit rate in the EE a lot less as compared to the impact on the spread in a frictionless market. Consequently, aggregate credit, investment, and asset prices contract less severely compared to an economy with fewer frictions. This makes domestic bank's net worth and leverage reduce less. As a result, the GDP of EE with higher financial frictions is less affected in the face of a foreign shock compared to an economy with lower frictions.

Although the dynamic impacts of foreign interest rate rise are favourable for the economy with greater financial frictions, the comparison of the steady-state values between the two economies, as shown in Table 4.7, reveals that in the long run, the economy with lower financial frictions enjoys the benefits of greater cross-border flows. This long-term effect is similar to the one put forward for the high financial integration case earlier. In particular, because of the worse agency problem under greater financial frictions, the global bank lends to the EE bank only at a higher rate, resulting in more limited cross-border lending. This leads to greater inefficiency in the long run due to the higher cost of investment. In addition, the local bank needs to also build up more self-funding net worth in the face of more limited outside financing. In contrast, an economy with lower frictions provides credit to the real sector more efficiently thanks to greater cross-border borrowing from the global bank secured at lower rates. Consequently, investment and employment are higher and hence are consumption and GDP.

As above, we also calculate the volatilities of selected key variables following the foreign rate rise under two different levels of financial frictions. The first and the second columns in Table 4.8 show the volatilities as the deviation from the steady-state using the same method as above, whereas the third column represents the volatilities of the variables under high frictions relative to the benchmark case of low frictions. Negative numbers correspond to less volatility in the high friction EE following the shock and *vice versa*.

In line with the profile portrayed in Figure 4.6, it is clear that an economy with greater financial frictions exhibits much less volatilities following the foreign monetary policy contraction. Out of all the macroeconomic and financial variables considered, only the real exchange rate is affected more in less developed financial markets. This finding is supported by MacDonald (2017), who finds that countries with higher market frictions saw less fluctuations in equity prices, long-term domestic bond yield, and domestic exchange rate on impact from the US LSAP.

Overall, an emerging economy with greater frictions in its banking sector is less likely to be affected by external financial disturbances compared to one smaller frictions. Notwithstanding this, however, a country with fewer impediments enjoys the benefit of more ample international borrowing and hence greater funding. It appears that the price of having such benefits is more synchronization of the domestic macroeconomic and financial conditions with those of the global economy, particularly during crisis episodes.

4.8.2 The role of financial development and the effectiveness of MaP

Table 4.9 presents the impact of the foreign interest rate rise on domestic outcomes under greater financial frictions as a proxy for the level of financial development. Clearly the effectiveness of each MaP instrument varies with the scale of financial frictions. MaP that targets foreign borrowing (FB) is effective in curbing volatilities in almost all variables that we consider, followed by MaP that targets loan-to-GDP ratio (LG). In contrast, MaP that utilizes credit growth as the instrument (CG) appears to increase volatilities in almost all variables.

If the implementation of MaP is mainly to reduce fluctuations in credit growth, an economy with high financial frictions is better off with MaP that reacts to the loan-to-GDP ratio (LG) and foreign borrowing (FB). However if the objective of the MaP is to curb the build-up of asset price bubbles, then MaP with leverage ratio (LR) and foreign borrowing (FB) as instruments work better.

4.9 Conclusion

This paper examined how the recent lift-off by the US Fed - the exit from the near-zero interest rates policy- is likely to impact on emerging economies and the effectiveness of macroprudential policy as a defence against the unfavourable implications on the domestic economy. It then explored whether the effectiveness of macroprudential policy in defending against the foreign interest rate shock varies with the degree of financial integration between the domestic and the global economy and the type of exchange rate regime in the domestic economy.

Central to our analysis is the cross-border bank lending as the main channel of transmission of shocks from the monetary contraction in the centre economy. As a consequence, the Fed lift-off is followed by a slowing down in cross-border bank flows to the emerging economy, leading to the real exchange rate depreciation, a reduction in the aggregate credit and investment. Output contracts in the short run, but improves in the long run due to the terms of trade gains from the exchange rate depreciation.

In curbing fluctuations arising from the US interest rate rise, the macroprudential policy that targets the foreign bank borrowing performs best in most scenarios, suggesting that policy that focuses on the main channel of cross-border spill-overs is an effective defence mechanism. This is followed by a macroprudential policy that is tied to the loan-to-GDP ratio. In a great majority of the cases, macroprudential policy is effective in minimizing volatilities in credit growth, regardless of its type.

We then examined the role of varying the degree of domestic economy's integration with the global financial markets on the effectiveness of macroprudential policy in defending against the foreign interest rate shock. We find that with restricted capital mobility, the unfavourable impact of the foreign interest rate rise is curtailed; there is a smaller reduction in the foreign bank flows, thus a smaller reduction in the aggregate credit to the real sector, and hence in consumption and GDP. However, the domestic economy experiences greater fluctuations in financial variables such as asset prices, leverage ratio, interest rate spread, and net worth of local banks in this case. Put differently, low financial integration appears beneficial in the short-run in the form of fewer fluctuations, yet in the long run, impediments to capital mobility prevents the economy from reaping the benefits in the form of lower cross-border borrowing rate and greater capital inflows. We show that the effectiveness of macroprudential policy improves under restricted capital mobility, reducing fluctuations in most financial variables quite significantly.

The choice of the exchange rate regime also plays a key role in the impact of the Fed lift-off on the domestic outcomes. We find that the unfavourable impact of the foreign interest rate rise on the domestic outcomes is greater under a fixed exchange rate regime. This is mostly due to the loss of exchange rate as a shock absorber, which takes the form of depreciation under a flexible exchange rate regime and hence reversal of some of the costs arising from the foreign rate rise. Interestingly, however, limiting the exchange rate flexibility improves the effectiveness of the macroprudential policy.

Overall, our results point to the importance of adopting a combination of policies against global financial disturbances including macroprudential measures, restrictions to capital flows and restricting exchange rate flexibility. Our findings point to the interaction between macro-prudential and capital flow policies as playing a key role in successfully defending against global financial challenges.

Table 4.1: List of parameters and the values.

Parameters	Description	Value	Data/ Source
Households			
β	Time preference factor	0.99	BDL
σ	Household risk aversion	1	AKGLS
ψ	Elasticity of labour supply	0.276	BDL
Wholesale firms			
α	Capital share	0.3	BDL
δ	Capital depreciation	0.025	BDL
Capital producing firms			
ς	Adjustment cost of investment	2	AKGLS
Retail firms			
ψ	Calvo parameter	0.8	BDL
σ_p	Micro elasticity of substitution	6	BDL
n	Population's size of EE	0.15	BDL
ν_e	Home bias EE, and AE	0.80	AKGLS
ν_c		0.97	
υ	Trade elasticity	1.5	AKGLS
Financial intermediaries			
θ	Exit rate of bankers	0.9	AKGLS
$\kappa^e = \kappa^c$	ICC parameters	0.3	AKGLS
$\delta_{T,e} = \delta_{T,c}$	Transfer rate to new bankers	0.004	BDL
Monetary policy			
λ_r	Taylor rule autocorrelation parameter	0.85	BDL
λ_p	Taylor rule inflation parameter	1.2	BDL
λ_y	Taylor rule growth parameter	0.2	BDL
Macroprudential policy			
ρ_τ	Macroprudential policy persistence	0.1	
α_{lev}	MaP response to leverage	0.005	
α_{QKY}	MaP response to loan-to-GDP	0.005	
α_{cg}	MaP response to credit growth	0.005	
α_V	MaP response to foreign borrowing	0.005	
steady-state values matched			
Leverage ratio CE	Ratio of asset over capital	8.68	8.03-8.62
Leverage ratio EE		8.28	8.37
Spread CE (annual bps)	Lending and deposit spread	405	467
Spread EE (annual bps)		403	450

Note: BDL: Banerjee, Devereux, and Lombardo (2016), AKGLS: Agenor, Kharroubi, Gambacorta, Lombardo, da Silva (2017).

Table 4.2: The impact of foreign policy rate rise on volatilities in EE with full financial integration and a flexible exchange rate (the benchmark case).

Variables	High Financial Integration + Flexible ER								
	Volatilities					Relative to no MaP			
	No MaP	LR	LG	CG	FB	LR	LG	CG	FB
Macroeconomic									
GDP	11.82	14.60	11.34	12.04	11.36	0.235	**-0.040**	0.019	**-0.039**
Consumption	7.87	9.65	7.60	7.94	7.63	0.226	**-0.034**	0.009	**-0.031**
Employment	15.52	19.11	14.88	15.84	14.88	0.232	**-0.041**	0.021	**-0.041**
Investment	44.57	55.23	43.96	44.33	45.08	0.239	**-0.014**	**-0.005**	0.012
Financial									
Credit	12.45	16.71	12.04	12.41	12.26	0.342	**-0.033**	**-0.003**	**-0.015**
Asset price	19.08	15.09	19.35	20.59	19.06	**-0.209**	0.014	0.079	**-0.001**
Leverage ratio	156.49	159.56	147.40	338.03	137.31	0.020	**-0.058**	1.160	**-0.123**
Spread	9.24	5.85	9.61	10.72	9.17	**-0.367**	0.039	0.160	**-0.008**
Net worth	177.91	176.85	172.31	348.24	164.44	**-0.006**	**-0.032**	0.957	**-0.076**
Monetary									
Inflation	1.28	1.50	1.24	1.29	1.25	0.172	**-0.028**	0.008	**-0.022**
Interest rate	1.09	1.33	1.05	1.11	1.05	0.222	**-0.035**	0.018	**-0.031**
Foreign related									
RER	16.00	19.63	15.40	15.67	15.47	0.227	**-0.037**	**-0.021**	**-0.033**
Foreign borrowing	10.97	12.24	11.19	10.25	11.48	0.115	0.020	**-0.066**	0.046

Note: The table compares the magnitude of volatilities under each macroprudential regime against a benchmark of no macroprudential policy implementation. Bold numbers represent lower volatilities compared to the benchmark. In all scenarios, monetary policy is implemented through a standard Taylor rule. MaP: Macroprudential policy, LR: leverage ratio, LG: loan-to-GDP, CG: credit growth, FB: foreign borrowing.

Table 4.3: Comparison of steady-state values across two different levels of financial integration.

Steady-state values greater under *low* financial integration
Return on capital
Rate for foreign bank lending
Spread
Net worth bank
Steady-state values greater under *high* financial integration
GDP
Aggregate credit
Investment
Consumption
Employment
Cross-border banking lending
Leverage
Net capital inflows
Net foreign asset

Table 4.4: The impact of foreign policy rate rise on volatilities in EE with low financial integration and a fixed exchange rate regime.

Variables	Volatilities			Relative to Benchmark	
	Benchmark	Low FI	Fixed ER	Low FI	Fixed ER
Macroeconomic					
GDP	11.82	12.04	17.94	0.019	0.518
Consumption	7.87	6.83	9.13	**-0.132**	0.160
Employment	15.52	14.68	21.51	**-0.054**	0.386
Investment	44.57	46.91	68.48	0.053	0.537
Financial					
Credit	12.45	13.14	18.25	0.055	0.466
Asset price	19.08	19.86	30.00	0.041	0.572
Leverage ratio	156.49	160.63	215.51	0.026	0.377
Spread	9.24	9.66	13.97	0.045	0.511
Net worth of banks	177.91	184.57	248.21	0.037	0.395
Monetary					
Inflation	1.28	1.23	1.64	**-0.034**	0.286
Interest rate	1.09	1.09	2.40	0.007	1.210
Foreign related					
RER	16.00	14.28	17.48	**-0.108**	0.092
Foreign borrowing	10.97	8.05	13.00	**-0.266**	0.185

Note: The first column is the benchmark case with high financial integration and a flexible exchange rate regime. The second column presents volatilities under low financial integration with flexible exchange rate, whereas the third column exchange rate is fixed but financial integration is high. The forth and fifth columns present the second and third columns relative to benchmark values. Monetary policy is implemented in all scenarios, but no macroprudential policy is implemented.

Table 4.5: The effectiveness of macroprudential policy with *low* financial integration and flexible exchange rate.

Variables	Low Financial Integration + Flexible ER								
	Volatilities					Relative to no MaP			
	No MaP	LR	LG	CG	FB	LR	LG	CG	FB
Macroeconomic									
GDP	12.04	12.10	11.24	44.88	11.32	0.005	**-0.067**	2.726	**-0.060**
Consumption	6.83	7.32	6.62	25.64	6.63	0.071	**-0.032**	2.752	**-0.029**
Employment	14.68	15.07	13.90	54.84	13.94	0.026	**-0.053**	2.735	**-0.050**
Investment	46.91	44.50	39.50	48.24	40.34	**-0.051**	**-0.158**	0.028	**-0.140**
Financial									
Credit	13.14	12.99	11.56	31.90	11.85	**-0.012**	**-0.120**	1.428	**-0.098**
Asset price	19.86	16.51	16.54	16.51	16.41	**-0.168**	**-0.167**	**-0.169**	**-0.173**
Leverage ratio	160.63	57.06	58.64	60.42	56.01	**-0.645**	**-0.635**	**-0.624**	**-0.651**
Spread	9.66	7.35	7.96	7.79	7.72	**-0.240**	**-0.177**	**-0.194**	**-0.201**
Net worth	184.57	77.09	78.54	81.10	76.25	**-0.582**	**-0.574**	**-0.561**	**-0.587**
Monetary									
Inflation	1.23	1.28	1.20	4.14	1.21	0.038	**-0.026**	2.356	**-0.016**
Interest rate	1.09	1.10	1.02	4.09	1.03	0.003	**-0.070**	2.743	**-0.061**
Foreign related									
RER	14.28	16.40	14.97	58.98	15.13	0.148	0.048	3.131	0.060
Foreign borrowing	8.05	9.86	8.87	26.15	9.03	0.224	0.102	2.247	0.122

Note: The table compares the magnitude of volatilities under each macroprudential measure relative to the benchmark of no macroprudential policy. Bold numbers represent lower volatilities compared to the benchmark. MaP: Macroprudential policy, LR: leverage ratio, LG: loan-to-GDP, CG: credit growth, FB: foreign borrowing.

Table 4.6: The effectiveness of macroprudential policy with high financial integration and *fixed* exchange rate.

Variables	Fixed ER (High Financial Integration)								
	Volatilities					Relative to no MaP			
	No MaP	LR	LG	CG	FB	LR	LG	CG	FB
Macroeconomic									
GDP	17.94	22.63	17.32	18.09	17.43	0.262	**-0.035**	0.009	**-0.029**
Consumption	9.13	11.41	8.87	8.94	8.94	0.250	**-0.028**	**-0.021**	**-0.021**
Employment	21.51	26.71	20.80	21.68	20.93	0.242	**-0.033**	0.008	**-0.027**
Investment	68.48	86.63	67.61	67.93	69.02	0.265	**-0.013**	**-0.008**	0.008
Financial									
Credit	18.25	25.12	17.72	17.88	17.99	0.376	**-0.029**	**-0.020**	**-0.014**
Asset price	30.00	25.55	30.12	32.90	29.84	**-0.148**	0.004	0.097	**-0.005**
Leverage ratio	215.51	223.01	201.92	477.35	189.53	0.035	**-0.063**	1.215	**-0.121**
Spread	13.97	9.44	14.32	16.73	13.78	**-0.324**	0.025	0.198	**-0.013**
Net worth	248.21	250.09	239.78	488.75	230.15	0.008	**-0.034**	0.969	**-0.073**
Monetary									
Inflation	1.64	1.82	1.63	1.63	1.63	0.110	**-0.011**	**-0.006**	**-0.006**
Interest rate	2.40	2.69	2.38	2.37	2.39	0.121	**-0.010**	**-0.011**	**-0.005**
Foreign related									
RER	17.48	22.96	16.70	16.84	16.83	0.314	**-0.044**	**-0.036**	**-0.037**
Foreign borrowing	13.00	14.73	13.31	12.16	13.58	0.133	0.024	**-0.065**	0.044

Note: The table compares the magnitude of volatilities under each macroprudential instrument implementation relative to the benchmark of no macroprudential. Bold numbers represent lower volatilities compared to no macroprudential policy. MaP: Macroprudential policy, LR: leverage ratio, LG: loan-to-GDP, CG: credit growth, FB: foreign borrowing.

Table 4.7: Comparison of steady-state values across two different levels of financial frictions.

Steady-state values greater under *high* financial friction
Return on capital
Rate for foreign bank lending
Spread
Net worth bank
Steady-state values greater under *low* financial friction
GDP
Aggregate credit
Investment
Consumption
Employment
Cross-border banking lending
Leverage
Net capital inflows
Net foreign asset

Table 4.8: The impact of foreign interest rate rise on volatilities in EE with *high* financial frictions.

Variables	Volatilities		Relative to benchmark
	Benchmark	High friction	High friction
Macroeconomic			
GDP	11.82	11.74	**-0.007**
Consumption	7.87	7.52	**-0.044**
Employment	15.52	15.22	**-0.019**
Investment	44.57	38.40	**-0.138**
Financial			
Credit	12.45	11.48	**-0.078**
Asset price	19.08	11.12	**-0.417**
Leverage ratio	156.49	69.11	**-0.558**
Spread	9.24	4.17	**-0.549**
Net worth of banks	177.91	84.62	**-0.524**
Monetary			
Inflation	1.28	1.26	**-0.014**
Interest rate	1.09	1.06	**-0.024**
Foreign related			
RER	16.00	16.23	0.014
Foreign borrowing	10.97	9.44	**-0.140**

Note: The table compares the magnitude of volatilities assuming no macroprudential policy implementation. Bold numbers represent lower volatilities compared to benchmark case of low financial frictions. In all scenarios, monetary policy is implemented according to a standard Taylor rule.

Table 4.9: The effectiveness of macroprudential policy on volatilities in EE with *high* financial frictions.

Variables	High Financial Friction (High Financial Integration + Flexible ER)								
	Volatilities					Relative to no MaP			
	No MaP	LR	LG	CG	FB	LR	LG	CG	FB
Macroeconomic									
GDP	11.74	12.20	11.21	12.34	11.07	0.039	**-0.045**	0.051	**-0.057**
Consumption	7.52	7.69	7.30	7.98	7.23	0.023	**-0.030**	0.061	**-0.038**
Employment	15.22	15.63	14.54	16.24	14.33	0.027	**-0.044**	0.067	**-0.058**
Investment	38.40	38.68	38.48	38.63	38.58	0.007	0.002	0.006	0.005
Financial									
Credit	11.48	12.06	11.12	11.79	11.06	0.051	**-0.032**	0.027	**-0.037**
Asset price	11.12	9.29	11.26	12.09	10.73	**-0.164**	0.013	0.088	**-0.035**
Leverage ratio	69.11	50.35	60.19	141.28	52.30	**-0.271**	**-0.129**	1.044	**-0.243**
Spread	4.17	3.19	4.27	4.84	3.93	**-0.234**	0.024	0.161	**-0.056**
Net worth	84.62	64.98	76.93	154.80	69.35	**-0.232**	**-0.091**	0.829	**-0.180**
Monetary									
Inflation	1.26	1.30	1.22	1.30	1.22	0.031	**-0.029**	0.034	**-0.034**
Interest rate	1.06	1.10	1.02	1.11	1.01	0.034	**-0.039**	0.048	**-0.050**
Foreign related									
RER	16.23	17.26	15.66	16.54	15.63	0.063	**-0.035**	0.019	**-0.037**
Foreign borrowing	9.44	10.09	10.15	8.81	10.68	0.069	0.075	**-0.066**	0.132

Note: The table compares the magnitude of volatilities under each macroprudential measure relative to the benchmark of no macroprudential. Bold numbers represent lower volatilities compared to the benchmark. MaP: Macroprudential policy, LR: leverage ratio, LG: loan-to-GDP, CG: credit growth, FB: foreign borrowing.

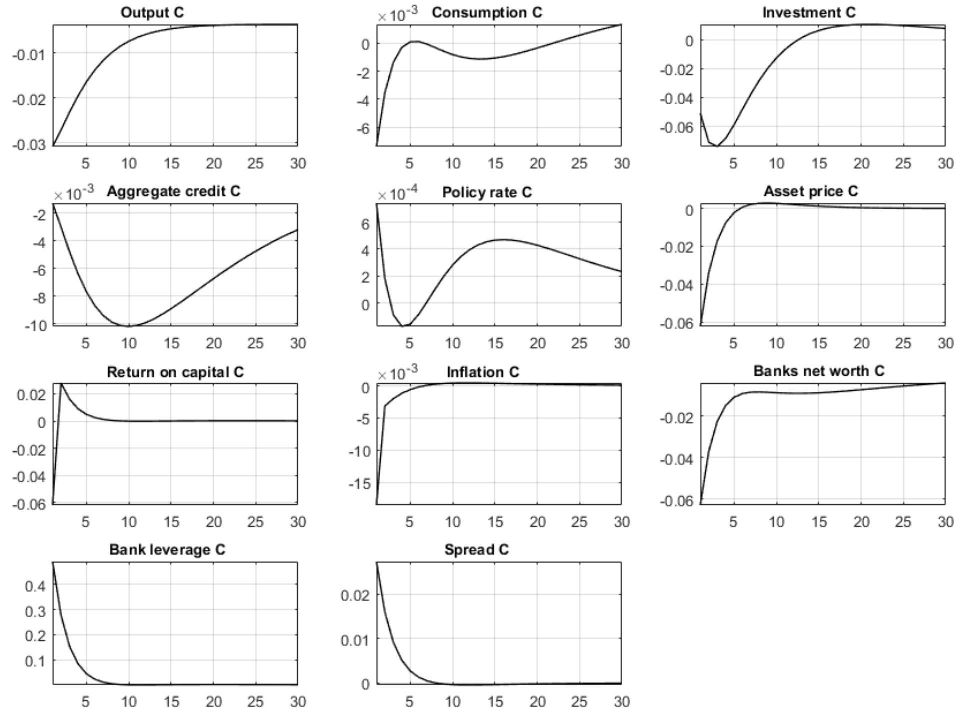


Figure 4.1: The impact of positive shocks to R* on outcomes in CC in the benchmark case, in percent deviation from steady-state.

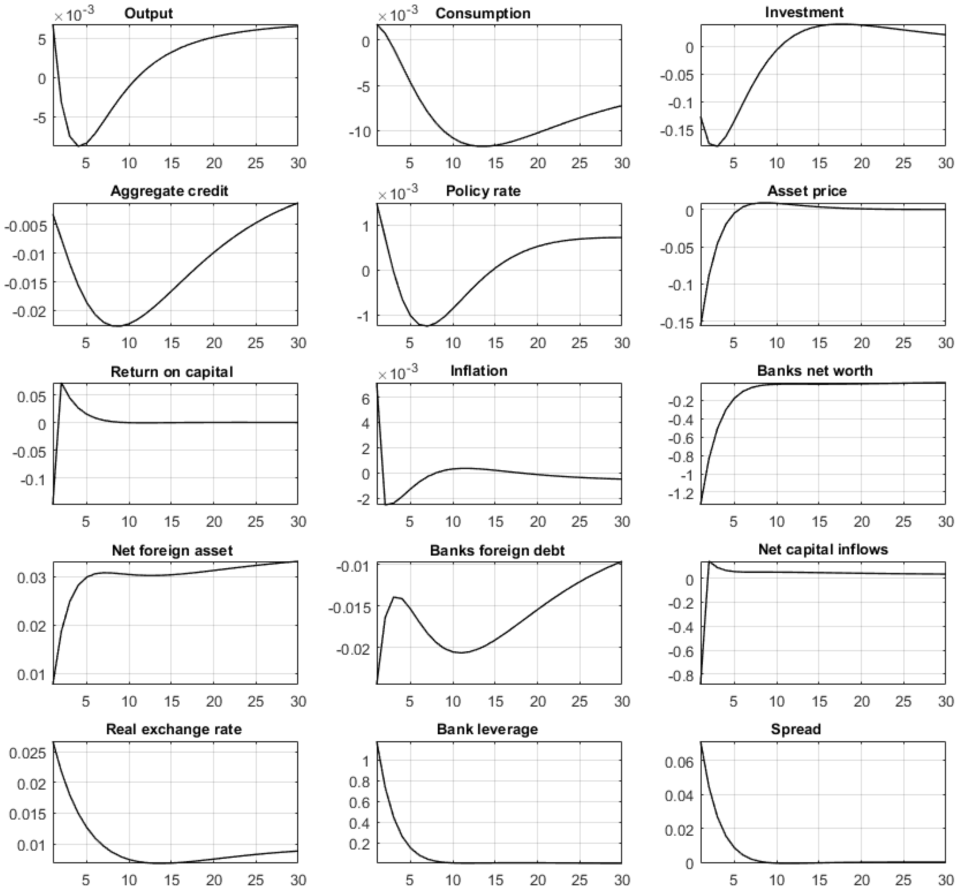


Figure 4.2: The impact of positive shocks to R* on outcomes in EE in the benchmark case, in percent deviation from steady-state.

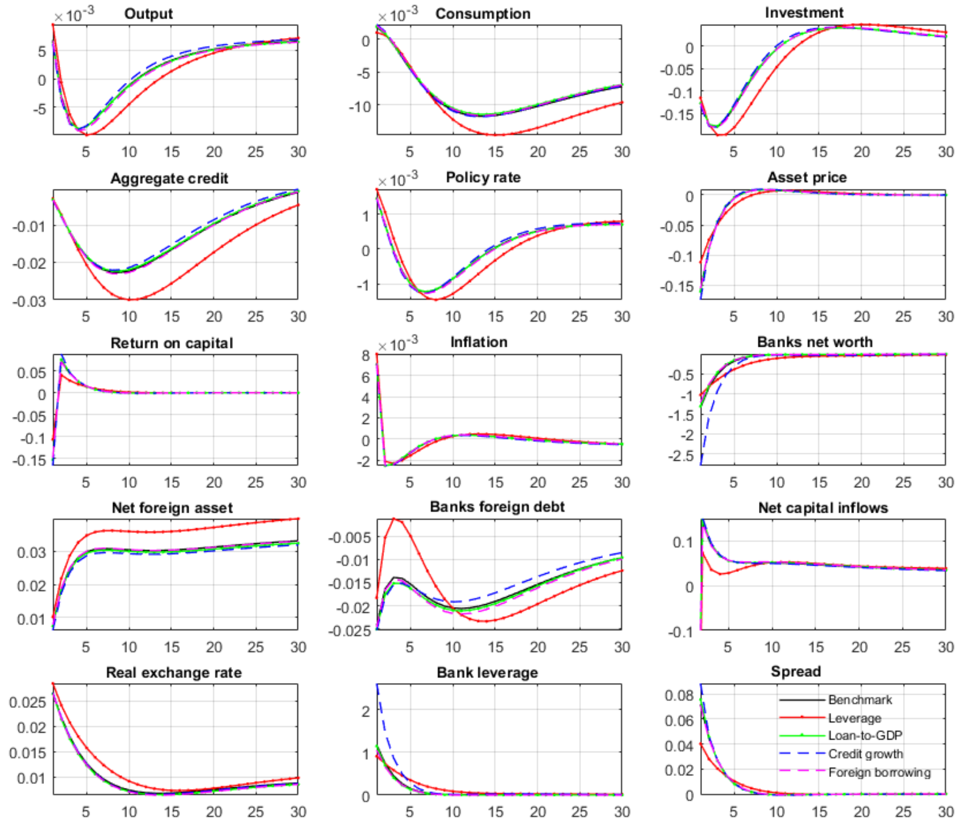


Figure 4.3: The effectiveness of the four macroprudential measures as defense against the positive shock to R*, in percent deviation from steady-state.

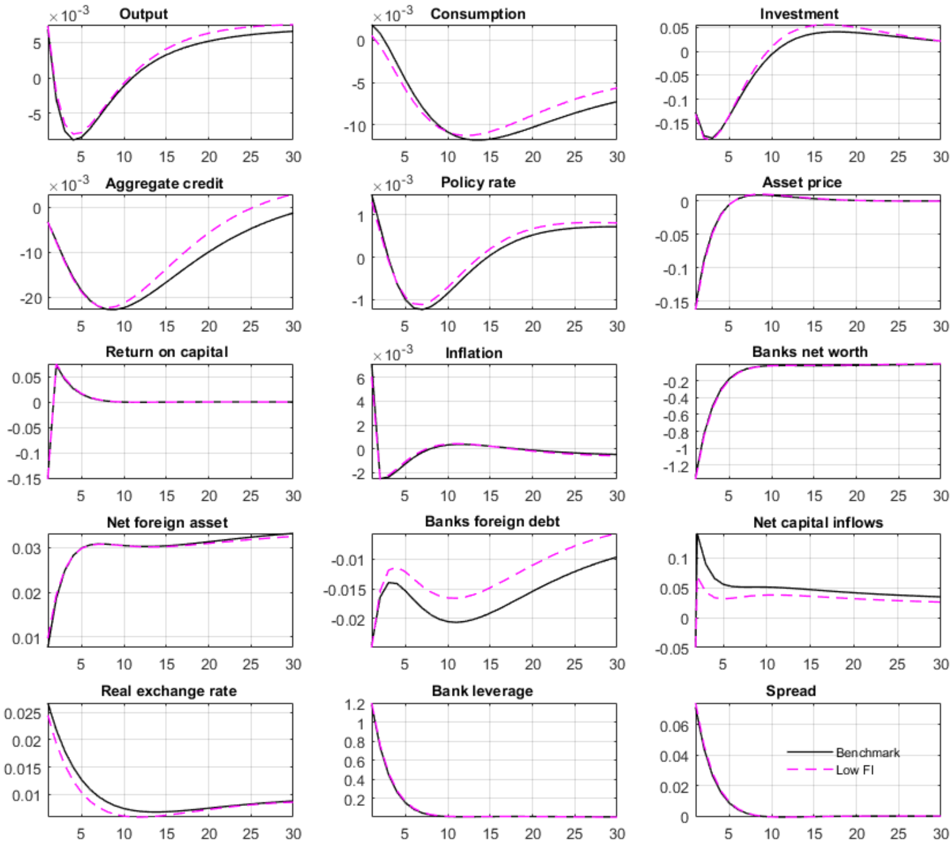


Figure 4.4: The impact of positive shocks to R* under different financial integration levels, in percent deviation from steady-state.

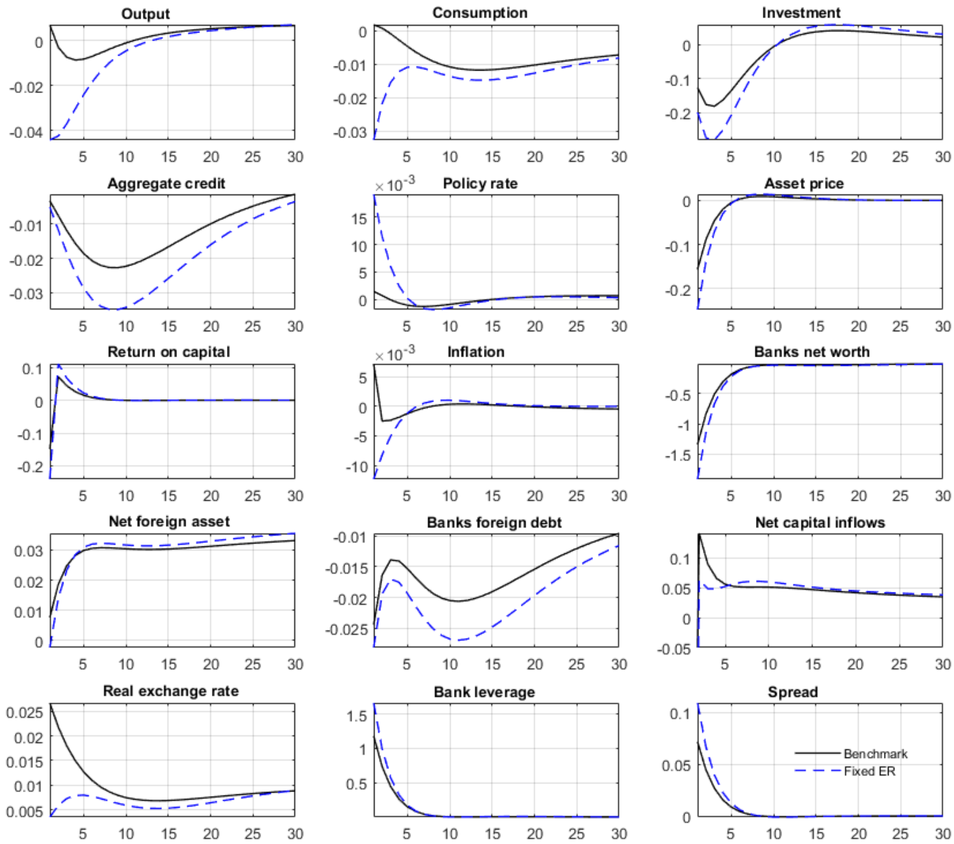


Figure 4.5: The impact of positive shocks to R* under fixed and flexible exchange rate regimes, in percent deviation from steady-state.

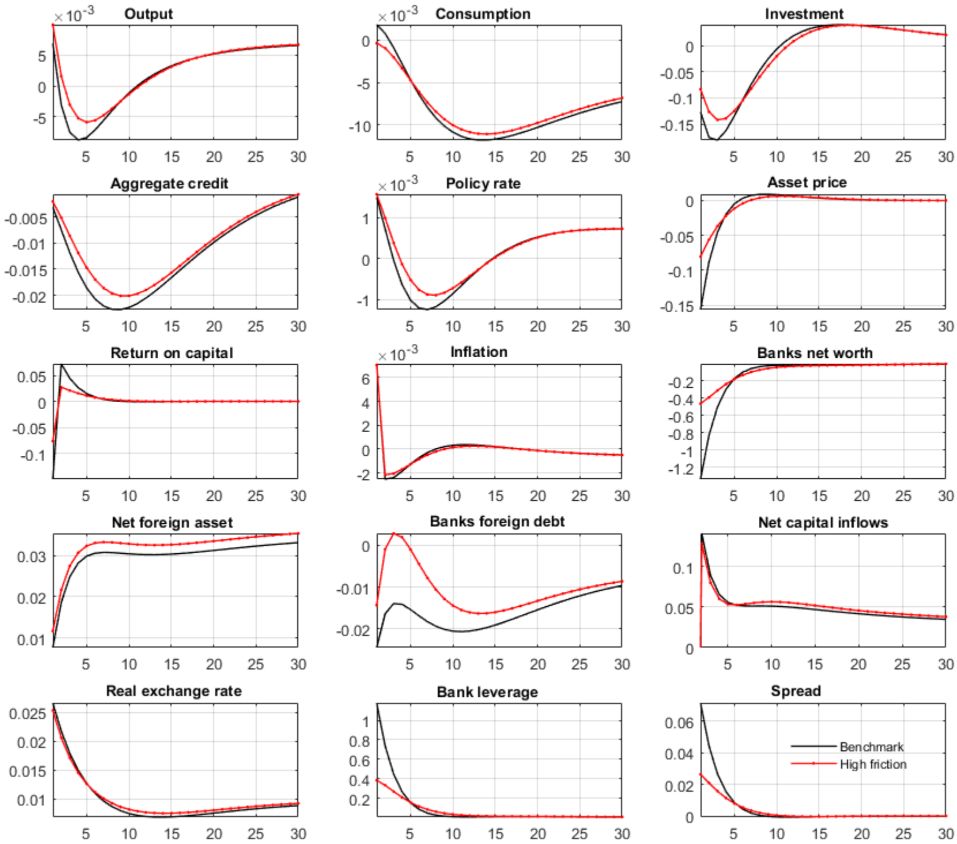


Figure 4.6: The impact of positive shocks to R* under different levels of financial frictions, in percent deviation from steady-state.

Chapter 5

Global Liquidity, Global Banks' Connectedness Network, and Monetary Policy

5.1 Introduction

International banks have an increasingly important role in facilitating financial globalization. They provide global liquidity -an ease of financing condition- by providing cross-border and/or foreign currency financing. In this paper, we study the main determinants of global banking liquidity, and then map out the international banking interconnection across different countries and groups of countries in the world. Our research objective is to examine how the activities of global banks -i.e. financial institutions with international establishments- and monetary policy decisions by the centre economy affect global liquidity, and how they facilitate monetary spillovers across borders. Unlike most studies on the cross-border banking activities which use data on a very small number of countries, we use cross-border banking claims and liabilities data from 35 countries from the Bank for International Settlements (BIS) locational statistics to establish the banking connectedness network. Our main contribution to the literature is twofold: (a) we uncover the determinants of global banking liquidity in the aggregate; and (b) we establish how global banks in different countries are interconnected.

The importance of studying the effects of shocks on global variables to global liquidity; and global banks' cross-border dynamics is to explain why certain variables of different countries increasingly show co-movement. On a policy front, the global banks' connectedness map can help inform policymakers of the existence of a cross-border channel of transmission, which often intensifies during crisis periods. Another important policy implication is that, if the international funding liquidity channel is strong, the strength of domestic monetary policy transmission mechanism in affected economies is subjected to strong influence from foreign monetary conditions. Foreign monetary influence may dampen or exaggerates the domestic channel of monetary policy transmission.

This paper uses two sets of analysis to perform the empirical analysis on banking statistics data. The first set of analysis carries out the analysis on a globally aggregated level using global variables, whereas the second set of analysis performs the analysis using banking data on the country level. The aim of the first set of analysis is to examine the relationship between global liquidity and several selected global economic variables in order to understand potential main determinants of global liquidity and how they interact. We perform a Vector Auto-Regression (VAR) analysis to the global liquidity, trade-weighted US Dollars value against major currencies of trading partners, US monetary policy, T-Bill Euro Dollar (TED) spread, and global credit-to-GDP gaps. The global liquidity variable is the globally aggregated cross-border banking borrowing and lending, thus the analysis of the global liquidity does not consider the cross-country direction of bank funding liquidity. The global liquidity variable is the Bank for International Settlements (BIS) locational statistic on cross-border banking position plus local lending in foreign currency, aggregated throughout all BIS reporting countries.

The second set of analysis applies the Global Vector Auto-Regression (GVAR) technique due to Pesaran et al. (2004) on the international banking claims, liabilities, and interbank conditions across 35 countries from the fourth quarter of 2003 to the third quarter of 2016. In addition, we include the global liquidity, US monetary policy, and USD value to our GVAR estimation as global variables that are potentially important for the cross-border banking claims and liabilities and interbank funding liquidity conditions among the countries. The GVAR helps to solve the dimensionality problem caused by the large number of countries and variables used in the analysis, using a certain weighting matrix to sum up the foreign influences to each country's VAR model. We use the estimated GVAR model to calculate the General Forecast Error Variance Decomposition (GFEVD) arising from shocks to each and every variable in the model. We then use the GFEVD to map international banking connectedness across different economies as well as groups of economies using the connectedness measure originally developed by (Diebold and Yilmaz, 2009; Diebold and Yılmaz, 2014), thereby measuring the direction and magnitude of funding liquidity across pairs of economies. To the best of our knowledge, this study is the first to use the BIS LBS in a GVAR framework. Our other novelty is that: we are the first attempting to exploit the BIS LBS to establish the global banking connectedness networks and draw them into layered graph presentation. The layered graph presentation allows us to rank countries (or groups of countries) -represented by nodes- neatly according to their degree of importance, with the top node being the most influential.

Global liquidity is a broad concept which the Bank for International Settlements (BIS) defines as the "ease of financing in the international financial system" (BIS, 2011; Caruana, 2014; Azis and Shin, 2015). It encompasses the ability of banks and capital markets to fund real and financial assets. More broadly, global liquidity indicates market participants' perceptions and attitude toward risks, valuations, and profits that drive their willingness to provide lending to real economic activities and financial assets transactions. This ease of financing cycle is endogenous and tends to be procyclical. It accelerates and ceases with financial institutions' risk appetite and leverage (Caruana, 2014).

BIS classifies global liquidity into *official* liquidity – which is created by the monetary authorities– and *private* liquidity (BIS, 2011; Domanski et al., 2011). Quantitatively, private liquidity dominates official liquidity, thus this study only utilizes the *private* liquidity data. Although official liquidity is quantitatively smaller, the Federal Reserve's decision regarding the official liquidity of the US Dollar, for instance, is not only important in adjusting monetary conditions in the US, but also globally. This is due to the extensive use of major reserve currencies like the US Dollar, the Euro, the Pounds, and the Japanese Yen for international trade and financial settlements that has provided a cross-border channel of global liquidity interconnection.

Private liquidity is the ease of financing condition that is determined by private financial institutions' willingness to provide lending and take risks. Financial institutions induce market liquidity by their ability to become market makers in financial asset transactions. They provide funding liquidity to the real sector through credit creation and to other financial institutions through interbank market. In the international context, global private-induced liquidity is associated with their willingness to provide cross-border and/or foreign currency financing.

Studies on the liquidity of the financial system have become increasingly important because of the financial system's strong connection to the real business cycle and its tendency to spillover across borders. The real business cycle paradigm in 1980's held that the financial system functions smoothly, justifying the exclusion of financial structures from mainstream macroeconomic theory. Later studies suggest that the financial cycle is not simply a passive reflection of the real economic business cycle, but is a major factor contributing to the severity of boom and bust periods in economic activity (Gertler, 1988; Bernanke et al., 1999). The latest global financial cycle period shows that excessive funding liquidity can build-up vulnerabilities in the financing of the real sector; whereas the shortage in funding liquidity can undermine credit creation and economic growth.

Financial conditions also tend to spillover across borders even when cross-border capital flows do not seem unusually high (Caruana, 2014). From the point of view of emerging economies, capital inflows expand economic development opportunities by reducing the cost of financing. The establishment of foreign financial institutions also allows local financial institutions to learn from financial best practices as well as introduce competition to lower inefficiencies. Moreover, it is commonly agreed that multinational banks contribute to financial stability in host markets during *local* financial turmoil. Cetorelli and Goldberg (2012a) find that global banks organization actively allocates funding source across its different affiliates located in various jurisdictions. Hence, the existence of an internal finance market within its broader organization helps the foreign bank in emerging economies contribute to financial stability during a *local* financial crisis.

Despite the opportunities financial integration has to offer, the 2007-08 global financial crisis demonstrated that it exposes emerging economies to international financial shocks. During this time, credit tightness in some advanced economies led to capital outflows in emerging economies which caused tightness in these economies. Global banks play a significant role here. They increase the risk of importing financial instability to host market during financial crisis originated in *home* market, albeit there are many nuances to this finding (Haas and Lelyveld, 2014; Moreno et al., 2010; Avdjiev et al., 2016; Cetorelli and Goldberg, 2012a,b,c). For instance, the loan supply reduction is less if the branch size in the host market is large, geographically close, more experienced, and when it is integrated into a network of domestic co-lenders (De Haas and Van Horen, 2012).

5.2 Literature Review

This study relates closely to two strands of literature. The first strand analyses the fluctuation of cross-border global banking liquidity and the strategic decision of global banks in their international operation which affects the dynamics of aggregate lending and borrowing across countries. The second strand relates to the method used in this study, i.e. the Global Vector Auto-Regression (GVAR) and the connectedness measures of network models.

The notion of the bank-based global funding liquidity arises from the policy discussion led by the Bank for International Settlements (BIS) Committee in the Global Financial System Report (BIS, 2011), particularly due to the impact of permissive credit conditions in financial centres that are transmitted across borders. The cross-border credit conditions' transmission brings about highly synchronised financial conditions and strong co-movement of debt flows and credit growth globally (Miranda-Agrippino and Rey, 2015; Rey, 2015).

Understanding the drivers of global liquidity is challenging as the perceived determinants interact in complex ways with each other and the global liquidity itself. BIS (2011) classifies three broad categories of global liquidity drivers, albeit intertwined: (a) macroeconomic factors (e.g. policy rates, interest rate differentials, and exchange rate policies); (b) other public sector factors (e.g. central bank liquidity policies and financial regulation); and (c) financial factors (e.g. financial intermediation structure and risk appetite).

Using a model of the international banking where global banks and local banks interact, Bruno and Shin (2015b) highlight that bank leverage cycle is the most important determinant of the transmission of financial conditions through cross-border banking flows. The study also underlines the close association between the bank leverage cycle with host country's currency appreciation. The prevalent use of the US Dollar as the major global reserve currency and the cheaper US Dollar bank funding rate reinforced the global banking system by extending the 'risk-taking channel' of monetary policy transmission to the international context (Azis and Shin, 2015; Bruno and Shin, 2015b). Takáts and Temesvary (2016) conclude that monetary shocks in a currency significantly affect cross-border bank lending flows in that currency, even when neither the lender nor the borrowing banks' country use that currency as their own. Nevertheless, cross-border banking flows can also have feedback effect to the USD exchange rate fluctuations (Gabaix and Maggiori, 2015). Cross-border bank lending is also influenced by bank's capital position and perceived risks (Azis and Shin, 2015).

Azis and Shin (2015) underline the important role of round-trip capital flows through the European banks lending in influencing US credit conditions in the run-up of the global financial cycle. The sharp drop in cross-border bank lending to emerging markets in the second half of 2011, as the Euro area crisis intensified, was a notable instance (Avdjiev et al., 2016). The apprehension of European banks activities in intermediating US dollar funding has raised understanding of the importance of using cross-border *gross* flows (Borio and Disyatat, 2011), as opposed to using cross-border *net* flows that led to the 'excess saving' and 'global savings glut' view widely used in studies mostly before the global financial crisis as in (Bernanke, 2005; Mendoza et al., 2009).

International parent banks manage liquidity on a global scale. They maximize the international bank holding's profit by deciding between parent funding and local funding of each individual affiliate and across all other affiliates given interest rate margins of the parents and local banks borrowings and lending (Galema et al., 2016; Cetorelli and Goldberg, 2012a,c). Thus, global banks have the capacity to insulate from local shock in host countries (including local monetary policy shock) compared to domestic banks (Cetorelli and Goldberg, 2012a). During a financial crisis in the parents' home countries, the affiliates' local deposits perform as a stabilizer for loan supply disruptions, but greater reliance on intra-bank funding disadvantages the affiliates as the parent's ability to sustain a stable deposit and long-term wholesale funding position deteriorates (Frey and Kerl, 2015). The lending capacity of foreign affiliates during the 2008-09 crisis slowed down twice as fast as domestic banks, and the effect is stronger if the banks' parent depends more on wholesale-market funding (Haas and Lelyveld, 2014). Moreover, there is competition for intra-bank funding between the affiliates serving different countries and an increasing concentration of resources on parent lending to the home market (Frey and Kerl, 2015). Therefore, the global banks' international presence contributes to the international propagation of shocks, as happened during the financial crisis of 2007 to 2009 (Cetorelli and Goldberg, 2012a; Frey and Kerl, 2015).

Studies classify the global banks' sources of funding under two broad headings: the internal and the external capital market. All funding that banks obtain from their broader internal organization falls under the heading of internal capital market, for example: funding from headquarters, if they are subsidiaries or affiliates, or from subsidiaries if they are the headquarter e.g. (Galema et al., 2016; Frey and Kerl, 2015; Cetorelli and Goldberg, 2012a,b,c; Haas and Lelyveld, 2014; Buch et al., 2016). External capital can be obtained from any sources other than banks' organization, like local deposits, other sources from host country, and cross-border interbank funding (Cetorelli and Goldberg, 2011; De Haas and Van Horen, 2012; Popov and Udell, 2012; Tintchev, 2013).

During a crisis, lending supply shocks to balance sheet in the foreign banks in developed-country has led to substantial supply lending shock to emerging economies (Cetorelli and Goldberg, 2011; De Haas and Van Horen, 2012; Popov and Udell, 2012; Cetorelli and Goldberg, 2012b). Cetorelli and Goldberg (2012b) find that on average, local lending by affiliates reduces by forty to fifty cents for every dollar transferred to the parent bank. The loan supply effect is significant through all three balance sheet channels: a contraction in direct, cross-border lending by foreign banks, a contraction in local lending by foreign banks' affiliates in emerging markets, and a contraction in loan supply through interbank, cross-border lending (Cetorelli and Goldberg, 2011). However, the magnitude of the negative shock is heterogeneous, depending on the branch size, where the internal fund transfer disproportionately bigger for larger banks (Cetorelli and Goldberg, 2012b). In addition, global banks reduced funding less from countries that are geographically close; where they are more experienced; where they operated a subsidiary; and where they were integrated into a network of domestic co-lenders (De Haas and Van Horen, 2012).

The second strand of literature relates to the method used in this study, i.e. the Global Vector Auto-Regression (GVAR) and the connectedness measures of network models. The GVAR, initially developed by Pesaran et al. (2004), is a global macroeconometric model that exploits advances in the analysis of cointegration systems to perform analysis in a global modelling framework. The attractiveness of the GVAR is that it tackles the dimensionality problem of data with large cross-section dimension and time series, using predefined matrices to impose the strength of bilateral relationship for each pair of countries in the study.

The rich nature of the data used for the GVAR, such as data for the global economy, provides a natural extension into the analysis of complex systems in a network type of model. Two leading examples of such network models are Billio et al. (2012) and Diebold and Yilmaz (2009, 2014). In these studies, financial institutions are represented as nodes within the network. Billio et al. (2012) model the network using a Granger-causal network, while Diebold and Yilmaz (2009, 2014) use error variance decomposition to develop the connectedness measures. The latter method has the advantage of measuring contemporaneous shocks, and it is able to not only map out the direction of linkages but also the strength of the connection between two nodes.

Greenwood-Nimmo et al. (2015a) extends the advances in the network analysis by integrating detailed multivariate country-specific macroeconomic factors into a global system and then maps the topography of the resulting global network. This study generalizes the originally developed connectedness measures which have been utilized to study either the multi-country univariate case or the single-country multivariate case. Greenwood-Nimmo et al. (2015b) applies the connectedness measures on the price and order flow of important currency markets in order to study the transmission of information between currency spot markets.

5.3 Econometric Methodology

5.3.1 First Analysis: VAR to Global Variables

For the first set of analysis, we apply a VAR model to the global variables. The structural VAR is

$$AY_t = \sum_{j=1}^{p} C_j Y_{t-j} + \epsilon_t, \tag{5.1}$$

where the variables of interest for the VAR is the global liquidity variable, global credit-to-GDP gaps, US Dollar value, and US monetary policy rate, and TED spread. The structural white noise shocks are ϵ_t, with maximum lags j equal to 4 due to quarterly data.

The reduced form VAR can be written as:

$$Y_t = \sum_{j=1}^{p} B_j Y_{t-j} + u_t, \tag{5.2}$$

with

$$u_t = S\epsilon_t = A^{-1}\epsilon_t; \quad B_j = A^{-1}C_j \tag{5.3}$$

and the variance-covariance matrix of the reduced form VAR is

$$E_t[u_t u_t'] = E_t[SS'] = \Sigma. \tag{5.4}$$

For the impulse response functions, we use the generalized impulse response function (GIRF) as proposed by Pesaran and Shin (1998) for unrestricted vector autoregression models, which is built on Koop et al. (1996). Unlike the traditional orthogonalized impulse response analysis, the GIRF approach does not require orthogonalization of shocks and is invariant to the ordering of the variables in the VAR.

The GIRFs are defined by

$$\mathbf{GI}_x(n, \delta_j, \mathbf{\Omega_{t-1}}) = E(x_{t+n}|\epsilon_{jt} = \delta_j, \mathbf{\Omega}_{t-1}) - E(x_{t+n}|\mathbf{\Omega}_{t-1}) \tag{5.5}$$

where δ_j is the size of shock hitting the global economy at time t, $\mathbf{\Omega_{t-1}}$ is the non-decreasing information set denoting the known history of the economy up to time $t-1$, and n is the n-th period ahead impulse response.

Assuming that ϵ_t has a multivariate normal distribution,

$$E(\epsilon_t|\epsilon_{jt} = \delta_j) = (\sigma_{1j}, \sigma_{2j}, \ldots, \sigma_{mj})'\sigma_{jj}^{-1}\delta_j = \mathbf{\Sigma e}_j\sigma_{jj}^{-1}\delta_j. \tag{5.6}$$

where σ_{jj} is the (j, j) element of $\mathbf{\Sigma}$, and e_j is a vector having unity at the j-th position and zeros elsewhere.

The $m \times 1$ vector of the (unscaled) generalized impulse response of the effect of a shock in the jth equation at time t on x_{t+n} is given by

$$\left(\frac{\mathbf{D_n \Sigma e_j}}{\sqrt{\sigma_{jj}}}\right)\left(\frac{\delta_j}{\sqrt{\sigma_{jj}}}\right), \quad n = 0, 1, 2, \ldots \tag{5.7}$$

where $\mathbf{D_n}$ is the n-th coefficient matrix from the moving average representation of the VAR model.

By setting $\delta_j = \sqrt{\sigma_{jj}}$, the scaled GIRF is

$$\psi_j^g(n) = \sigma_{jj}^{-\frac{1}{2}}\mathbf{D_n \Sigma e_j}, \quad n = 0, 1, 2, \ldots, \tag{5.8}$$

which measures the effect of one standard error shock to the jth equation at time t on expected values of x at time $t+n$.

5.3.2 Second Analysis: Cross-country Banking Interconnection

We follow the connectedness measure originally developed by Diebold and Yilmaz (2009) and Diebold and Yılmaz (2014), and extended by later studies such as Greenwood-Nimmo et al. (2015a) and Greenwood-Nimmo et al. (2015b). The connectedness measures are based on the forecast error variance decomposition (FEVD) of a p-th order vector autoregression for the $m \times 1$ vector of endogenous variables $\mathbf{y}_t$. The use of the FEVD is based on the notion that the dynamics of variable i caused by shock to variable j provides a directional measure of the association between these variables. An interesting feature from this approach is that the FEVDs are based on the estimated parameters and covariance matrix of the VAR system without any additional restrictions apart from the usual estimation and identification restrictions.

The claims in country i can be written as follows:

$$C_{it} = \lambda_i L_{it} + \boldsymbol{\lambda}^{*\prime}_{\boldsymbol{ci}} \mathbf{L}^*_{\mathbf{it}} + \boldsymbol{\gamma}^{*\prime}_{\boldsymbol{ci}} \mathbf{C}^*_{\mathbf{it}} + \xi_{cit}, \tag{5.9}$$

whereas the liabilities is as follows:

$$L_{it} = \gamma_i C_{it} + \boldsymbol{\gamma}^{*\prime}_{\boldsymbol{li}} \mathbf{C}^*_{\mathbf{it}} + \boldsymbol{\lambda}^{*\prime}_{\boldsymbol{li}} \mathbf{L}^*_{\mathbf{it}} + \xi_{lit}, \tag{5.10}$$

where C_{it} denotes the cross-border claims of country i to rest of the world, L_{it} is the cross-border liabilities of country i to rest of the world, λ_i is the long-run (equilibrium) impact of the cross-border liabilities in the i-th economy on the cross-border claims of economy i, γ_i is the long-run (equilibrium) impact of the cross-border claims in the i-th economy on the cross-border liabilities of economy i. $\mathbf{L}^*_{\mathbf{it}} = (L_{1t}, \ldots, L_{i-1,t}, L_{i+1,t}, \ldots, L_{Kt})'$ is a $(K-1) \times 1$ vector recording the cross-border liabilities in the remaining $K-1$ economies, $\mathbf{C}^*_{\mathbf{it}} = (C_{1t}, \ldots, C_{i-1,t}, C_{i+1,t}, \ldots, C_{Kt})'$ is a $(K-1) \times 1$ vector recording the cross-border claims in the remaining $K-1$ economies, $\boldsymbol{\lambda}^{*\prime}_{\boldsymbol{ci}} = (\lambda_1, \ldots, \lambda_{i-1}, \lambda_{i+t}, \ldots, \lambda_K)$ is a $(K-1) \times 1$ vector of parameters capturing the long-run impacts of these $K-1$ liabilities on the claims of economy i, and , $\boldsymbol{\gamma}^{*\prime}_{\boldsymbol{ci}} = (\gamma_1, \ldots, \gamma_{i-1}, \gamma_{i+t}, \ldots, \gamma_K)$ is a $(K-1) \times 1$ vector of parameters capturing the long-run impacts of these $K-1$ claims on the liabilities of economy i.

Estimating the dynamic form of equation 5.9 and 5.10 as a VAR is infeasible with available datasets due to the curse of dimensionality. With K economies in which we observe both the cross-border claims and liabilities, the dimension of the p-th order VAR model would be $2K(2Kp+1)$. To overcome this issue, we follow the GVAR approach due to Pesaran et al. (2004).

Following this approach, we estimate a set of K market-specific VAR models, each of which does not include the foreign cross-border liabilities directly but rather a weighted average of these $(K-1)$ foreign cross-border liabilities. The aggregate foreign cross-border claims with respect to economy i is defined as $L_{it}^{*\prime} = \sum_{j=1}^{K} w_{ij} L_{jt}$, where $w_{ij} \geq 0$ are the set of granular weights which satisfy $\sum_{j=1}^{K} w_{ij} = 1$ and $w_{ii} = 0$. The weight assigned to economy i against j is based on economy i's consolidated positions of its internationally active banking groups in economy j from the BIS consolidated banking statistics. The weight matrix is time-invariant. The matrix is calculated such that the greater weight is assigned to country j where country i international banks has the larger exposure.

With the use of the weighting matrix, equation 5.9 is thus modified as follows:

$$C_{it} = \lambda_i L_{it} + \lambda_{ci}^{*} L_{it}^{*} + \gamma_{ci}^{*} C_{it}^{*} + \xi_{cit}, \tag{5.11}$$

whereas equation 5.10 is as follows:

$$L_{it} = \gamma_i C_{it} + \gamma_{li}^{*} C_{it}^{*} + \lambda_{li}^{*} L_{it}^{*} + \xi_{lit}, \tag{5.12}$$

where λ_{ci}^{*} and γ_{ci}^{*} capture the cross-border claims impact of the weighted-average foreign liabilities and foreign claims respectively, whereas γ_{li}^{*} and λ_{li}^{*} represent the cross-border liabilities impact of the weighted-average foreign claims and foreign liabilities, respectively. Embedding the long-run relationship, (5.11), into an otherwise unrestricted VAR(p) model and assuming that L_{it}^{*} and C_{it}^{*} are weakly exogenous, we obtain the following market-specific Vector Error Correction Model (VECM):

$$\Delta \mathbf{X}_{it} = \mathbf{\Lambda_i} \Delta \mathbf{X}_{it}^{*} + \boldsymbol{\alpha}_i \boldsymbol{\beta}_i' \mathbf{Z}_{i,t-1} + \sum_{j=1}^{p-1} \mathbf{\Gamma}_{ij} \Delta \mathbf{Z}_{i,t-j} + \boldsymbol{\epsilon}_{it}, \tag{5.13}$$

where $\mathbf{X}_{it} = (C_{it}, L_{it})'$ is a 2×1 vector of endogenous variables containing the cross-border claims and liabilities for economy i, $\mathbf{X}_{it}^* = (C_{it}^*, L_{it}^*)'$ is a 2×1 vector of weakly exogenous variables containing the *foreign* cross-border claims and liabilities for economy i, $\mathbf{Z}_{it} = (\mathbf{X}_{it}', \mathbf{X}_{it}^*)'$, $\boldsymbol{\beta}_i$ is vector of cointegrating parameters, and $\boldsymbol{\alpha}_i$ is vector of adjustments parameters.

The inclusion of the foreign cross-border liabilities variables in the market-specific VAR models explicitly accommodates the modelling of linkages among different economies' cross-border bank positions. With the K estimated market-specific VAR models, we can then combine them into the GVAR framework due to Pesaran et al. (2004). First, equation 5.13 can be rewritten equivalently as:

$$\mathbf{A}_{i0}\mathbf{Z}_{it} = \mathbf{A}_{i1}\mathbf{Z}_{i,t-1} + \mathbf{A}_{i1}\mathbf{Z}_{i,t-2} + \cdots + \mathbf{A}_{i,p}\mathbf{Z}_{i,t-p} + \varepsilon_{it}, \tag{5.14}$$

where $\mathbf{A}_{i0} = (\mathbf{I}_2, -\boldsymbol{\Lambda}_i), \mathbf{A}_{i1} = \mathbf{A}_{i0} + \boldsymbol{\alpha}_i\boldsymbol{\beta}_i' + \boldsymbol{\Gamma}_{i1}, \mathbf{A}_{ij} = \boldsymbol{\Gamma}_{i,j+1} - \boldsymbol{\Gamma}_{i,j}$ for $j = 2, \ldots, p-1$, and $\mathbf{A}_{ip} = -\boldsymbol{\Gamma}_{ip}$.

We then define the $m \times 1$ vector of global variables $\mathbf{X}_t = (\mathbf{X}_{1t}', \ldots, \mathbf{X}_{Kt}')'$ where $\mathbf{X}_{it} = (C_{it}, L_{it})'$ and $m = 2K$. It is possible to express $\mathbf{Z}_{it}$ compactly as:

$$\mathbf{Z}_{it} = \mathbf{W}_i\mathbf{X}_t, \quad i = 1, 2, \ldots, K, \tag{5.15}$$

where $\mathbf{W}_i$ is the $(2+1) \times 2K$ link matrix. We construct the $\mathbf{W}_i$'s as follows:

$$\mathbf{W}_i = \begin{pmatrix} \mathbf{R}_{i1} & \mathbf{R}_{i2} & \mathbf{R}_{i3} & \ldots & \mathbf{R}_{iK} \\ \mathbf{W}_{i1} & \mathbf{W}_{i2} & \mathbf{W}_{i3} & \ldots & \mathbf{W}_{iK} \end{pmatrix}, i = 1, \ldots, K, \tag{5.16}$$

where

$$\{\mathbf{R}_{ij}\}_{j=1}^K = \left\{ \begin{matrix} \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} & if \quad j \neq i \\ \mathbf{I}_2 & if \quad j = i \end{matrix} \right\} \tag{5.17}$$

$$\{\mathbf{W}_{ij}\}_{j=1}^K = [0 \quad w_{ij}], i = 1, \ldots, K, \tag{5.18}$$

and w_{ij} is the weight assigned to economy j in creating the weighted-average foreign cross-border liabilities variable from the perspective of economy i. Using equation (5.14) and (5.15) and stacking the results we obtain:

$$\mathbf{H}_0\mathbf{X}_t = \mathbf{H}_1\mathbf{X}_{t-1} + \cdots + \mathbf{H}_p\mathbf{X}_{t-p} + \boldsymbol{\varepsilon}_t, \tag{5.19}$$

$\boldsymbol{\varepsilon}_t = (\varepsilon'_{1t}, \varepsilon'_{2t}, \ldots, \varepsilon'_{Kt})'$ and $\mathbf{H}_j = (\mathbf{W}'_1\mathbf{A}'_{1j}, \mathbf{W}'_2\mathbf{A}'_{2j}, \ldots, \mathbf{W}'_K\mathbf{A}'_{Kj})'$ for $j = 0, 1, \ldots, p$. The reduced-form GVAR is finally obtained as:

$$\mathbf{X}_t = \mathbf{G}_1\mathbf{X}_{t-1} + \mathbf{G}_2\mathbf{X}_{t-2} + \cdots + \mathbf{G}_p\mathbf{X}_{t-p} + \boldsymbol{\xi}_t, \tag{5.20}$$

where $\mathbf{G}_j = \mathbf{H}_0^{-1}\mathbf{H}_j, j = 1, 2, \ldots, p$ and $\boldsymbol{\xi}_t = \mathbf{H}_0^{-1}\epsilon_t$. As in the GVAR literature, we allow the country-specific shocks to be weakly correlated across economies such that $E(\varepsilon_{it}\varepsilon'_{jt}) = \sum_{\varepsilon,ij}$ for $t = t'$ and 0 otherwise.

The GVAR model in equation 5.20 is first recast in its Wold representation as follows:

$$\mathbf{X}_t = \sum_{j=0}^{\infty} \mathbf{B}_j\boldsymbol{\xi}_{t-j}, \tag{5.21}$$

where the $\mathbf{B}_j$'s are evaluated recursively as: $\mathbf{B}_j = \mathbf{G}_1\mathbf{B}_{j-1} + \mathbf{G}_2\mathbf{B}_{j-2} + \cdots + \mathbf{G}_{p-1}\mathbf{B}_{j-p+1}, \quad j = 1, 2, \ldots,$ with $\mathbf{B}_0 = \mathbf{I}_m, \quad \mathbf{B}_j = 0$ for $j < 0$.

Following Pesaran and Shin (1998), the h-step ahead GFEVD is written as follows:

$$\varphi_{j\leftarrow i}^{(h)} = \frac{\sigma_{\varepsilon,ii}^{-1}\sum_{l=0}^{h-1}(\mathbf{e}'_j\mathbf{B}_l\mathbf{H}_0^{-1}\boldsymbol{\Sigma}_\varepsilon\mathbf{e}_i)^2}{\sum_{l=0}^{h-1}\mathbf{e}'_j\mathbf{B}_l\boldsymbol{\Sigma}_\xi\mathbf{e}_j} \tag{5.22}$$

for $i, j = 1, \ldots, m$ where $\sigma_{\varepsilon,ii}$ is the standard deviation of the residual process of the i-th equation in the VAR system, $\mathbf{e}_i$ is an $m \times 1$ selection vector whose i-th element is unity with zeros elsewhere and $\mathbf{e}_j$ is an $m \times 1$ selection vector whose j-th element is unity with zeros elsewhere. Note that $\varphi_{j\leftarrow i}^{(h)}$ denotes the contribution of a one-standard error shock to variable i to the h-step forecast error variance (FEV) of variable j.

To demonstrate the computation of the spillover and heatwave effects via the Diebold-Yilmaz method, consider the simplest possible setting with two markets ($K = 2$) and hence $m = 2K = 4$ variables in total, in the order of $C_{1,t}, L_{1,t}, C_{2,t}, L_{2,t}$. As such, at any forecast horizon h, the forecast error variance decomposition can be cross-tabulated as follows:

$$\mathbb{C}^{(h)} = \begin{bmatrix} \phi^{(h)}_{C_1 \leftarrow C_1} & \phi^{(h)}_{C_1 \leftarrow L_1} & \phi^{(h)}_{C_1 \leftarrow C_2} & \phi^{(h)}_{C_1 \leftarrow L_2} \\ \phi^{(h)}_{L_1 \leftarrow C_1} & \phi^{(h)}_{L_1 \leftarrow L_1} & \phi^{(h)}_{L_1 \leftarrow C_2} & \phi^{(h)}_{L_1 \leftarrow L_2} \\ \phi^{(h)}_{C_2 \leftarrow C_1} & \phi^{(h)}_{C_2 \leftarrow L_1} & \phi^{(h)}_{C_2 \leftarrow C_2} & \phi^{(h)}_{C_2 \leftarrow L_2} \\ \phi^{(h)}_{L_2 \leftarrow C_1} & \phi^{(h)}_{L_2 \leftarrow L_1} & \phi^{(h)}_{L_2 \leftarrow C_2} & \phi^{(h)}_{L_2 \leftarrow L_2} \end{bmatrix} \tag{5.23}$$

Note that equation (5.23) is structured such that the total h-step ahead FEV of the i-th variable in the system is decomposed into the elements of the i-th row of $C^{(h)}$. Meanwhile, the contributions of the i-th variable to the h-th step ahead FEV of all variables in the system are contained in the i-th column of $C^{(h)}$. Therefore, based on equation (5.23) and following Pesaran and Shin (1998) and Pesaran et al. (2004), the aggregate h-step ahead heatwave and spillover indices, denoted $H^{(h)}$ and $S^{(h)}$, respectively, can be computed as follows:

$$H^{(h)} = \frac{1}{m}\text{trace}(\mathbb{C}^{(h)}) \tag{5.24}$$

$$S^{(h)} = \frac{1}{m}(\mathbf{e}'\mathbb{C}^{(h)}\mathbf{e} - \text{trace}(\mathbb{C}^{(h)})) \tag{5.25}$$

where $\mathbf{e}$ is an $m \times 1$ vector of ones. Furthermore, we are also able to see the effect from the economy/country level as opposed to the variable level (via $\mathbb{C}^{(h)}$) or the systemwide aggregate level (via $H^{(h)}$ and $S^{(h)}$) as follows:

$$\begin{aligned} H^{(h)}_{1\leftarrow 1} &= \frac{1}{K}\left(\phi^{(h)}_{P_1\leftarrow P_1} + \phi^{(h)}_{P_1\leftarrow Q_1} + \phi^{(h)}_{Q_1\leftarrow P_1} + \phi^{(h)}_{Q_1\leftarrow Q_1}\right), \\ H^{(h)}_{2\leftarrow 2} &= \frac{1}{K}\left(\phi^{(h)}_{P_2\leftarrow P_2} + \phi^{(h)}_{P_2\leftarrow Q_2} + \phi^{(h)}_{Q_2\leftarrow P_2} + \phi^{(h)}_{Q_2\leftarrow Q_2}\right), \\ S^{(h)}_{1\leftarrow 2} &= \frac{1}{K}\left(\phi^{(h)}_{P_1\leftarrow P_2} + \phi^{(h)}_{P_1\leftarrow Q_2} + \phi^{(h)}_{Q_1\leftarrow P_2} + \phi^{(h)}_{Q_1\leftarrow Q_2}\right), \\ S^{(h)}_{2\leftarrow 1} &= \frac{1}{K}\left(\phi^{(h)}_{P_2\leftarrow P_1} + \phi^{(h)}_{P_2\leftarrow Q_1} + \phi^{(h)}_{Q_2\leftarrow P_1} + \phi^{(h)}_{Q_2\leftarrow Q_1}\right), \end{aligned}$$

where $H^{(h)}_{1\leftarrow 1}(H^{(h)}_{2\leftarrow 2})$ denotes the heatwave effect within country 1 (country 2) and $S^{(h)}_{1\leftarrow 2}(S^{(h)}_{2\leftarrow 1})$ denotes the spillover effect from country 2 to country 1 (from country 1 to country 2). Note that $H^{(h)}_{1\leftarrow 1} + S^{(h)}_{1\leftarrow 2} = 100$ and $H^{(h)}_{2\leftarrow 2} + S^{(h)}_{2\leftarrow 1} = 100$ by construction. The net connectedness between country 1 and country 2 can then be defined as follows:

$$N^{(h)}_1 = S^{(h)}_{2\leftarrow 1} - S^{(h)}_{1\leftarrow 2} \text{ and } N^{(h)}_2 = S^{(h)}_{1\leftarrow 2} - S^{(h)}_{2\leftarrow 1}$$

Table 5.1: Descriptive statistics of global liquidity and its determinants

	Global Liquidity	US Policy Rate	US Dollar Value	Global Credit-to-GDP Gaps	TED Spread
Obs	103	103	103	103	103
Mean	4.39	2.50	86.93	1.71	0.49
Median	3.30	3.04	86.67	1.21	0.42
Max	21.60	6.53	111.59	10.95	2.45
Min	-11.10	-2.89	69.56	-4.38	0.15
Std. Error	0.75	0.27	1.00	0.31	0.03
Std. Dev	7.62	2.79	10.19	3.14	0.35

In a more general setting with K markets, the sign of $N_i^{(h)}$ indicates whether market i is a net transmitter of shocks to the system ($N_i^{(h)} > 0$) or a net receiver of shocks from the system ($N_i^{(h)} < 0$). using these market connectedness measure we can examine the relative importance of the within-economy (heatwave) and cross-economy (spillover) information in explaining the cross-border borrowing and lending activity in each country.

5.4 Descriptive Statistics

5.4.1 First Set of Analysis: Global Liquidity and Its Determinants

5.4.1.1 Global Liquidity

Table 5.1 shows the descriptive statistics for the global liquidity flows and the several US and global data that are potentially important in explaining global liquidity. The data are quarterly starting from the first quarter of 1991 until the third quarter of 2016, 103 time points. Our data sources are shown in Table 5.2.

Figure 5.1 shows the plot of the global liquidity series. The global liquidity data is obtained from Table E1 of the Bank for International Settlements (BIS) data on global liquidity indicators. It is the non-seasonally adjusted flow of international banks' claims, which consists of globally aggregated data on interbank cross-border claims and banks' foreign currency local claims to local banks. The unit of the global liquidity flows is year-on-year change. On average,

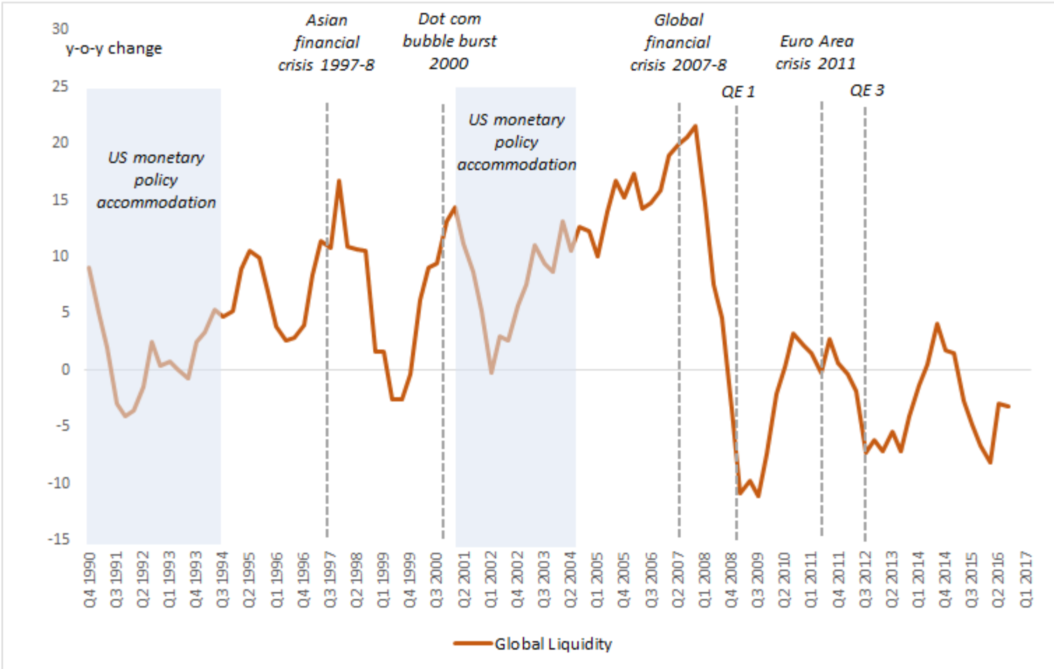


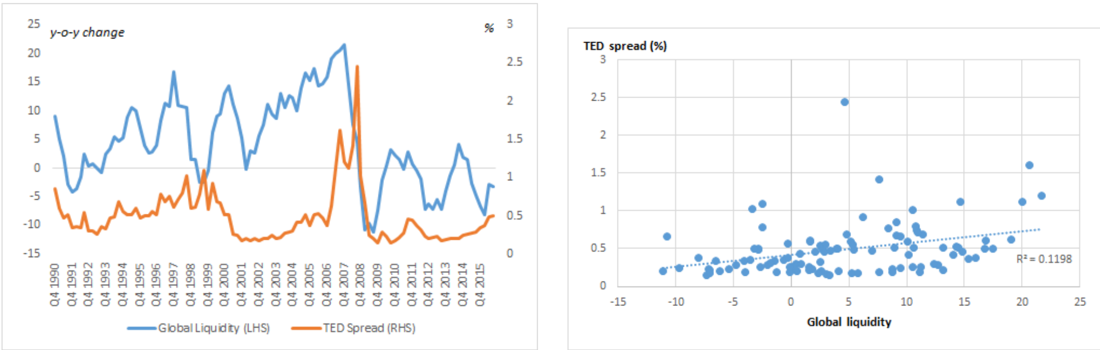
Figure 5.1: Global liquidity, source: Bank for International Settlements (BIS).

Table 5.2: Data source

Variable	Source
Global liquidity	Bank for International Settlements
US policy rate	Wu and Xia (2016) US shadow rate
Trade-weighted USD value	Datastream
Global credit-to-GDP gaps	Bank for International Settlements
TED spread	FRED US Federal Reserve St. Louis

the global liquidity flows increased by 5% y-o-y change throughout the period of observation, with the highest value of 22% in the last quarter of 2007 and the lowest value of -11% in the third quarter of 2009.

Figure 5.2a to 5.5 shows the scatter plot of global banking liquidity variable against its potential determinants which includes the TED spread, US policy rate, US Dollar value, and global credit-to-GDP gaps. The scatter plots describe the simple correlation between the global liquidity series and each of the other global variables, although the simple correlations do not necessarily say much about the magnitude or direction of causal relationship between the pair of variables.



(a) Global liquidity and TED spread

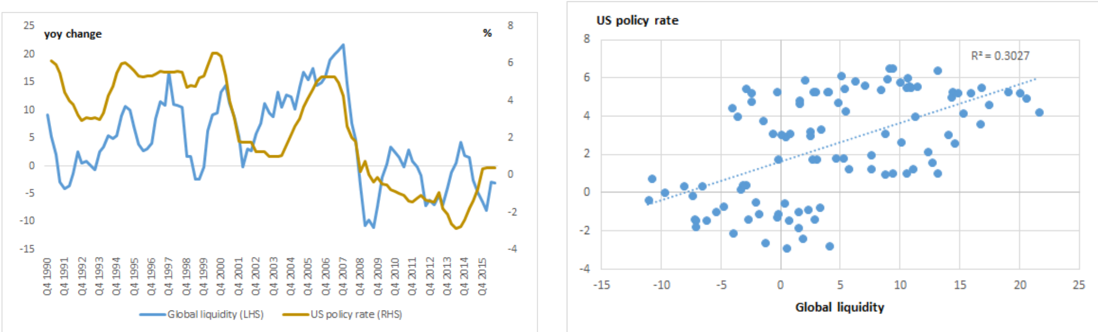
(b) Scatter plots

Figure 5.2: Global liquidity and TED spread, source: BIS and Datastream.

5.4.1.2 TED Spread

The first variable that we consider important for global liquidity is the interbank funding liquidity condition in the most important market. Two most important proxies for interbank funding liquidity condition are the spread between the London Interbank Offered Rate (LIBOR) and the Overnight Index Swap (OIS) for pound sterling. The other option is the TED spread - the spread between the 3-month LIBOR Rate based on US Dollar and 3-month US Treasury Bill. Because the OIS data are only available from 2006, the TED spread is used instead.

The TED spread is used as a perceived credit risk in the interbank market, because the LIBOR Rate is the rate participant banks offer to other banks in the LIBOR market for borrowing and lending, while the T-Bill rate is considered the risk-free interest rate. The higher the TED spread, the higher the credit risk participant banks perceive in their counterparty. Also, when the credit risk is high, the funding liquidity is low because banks with more liquidity become more resistant to lend. The scatter plot of the TED spread and global liquidity shows almost no correlation between the two series. However, a closer look seems to suggest that during the global financial crisis, the correlation becomes positive which is counterintuitive. This is possibly because the TED reacts to the crisis much faster than the slow-moving international banking liquidity flows.



(a) Global liquidity and US policy rate

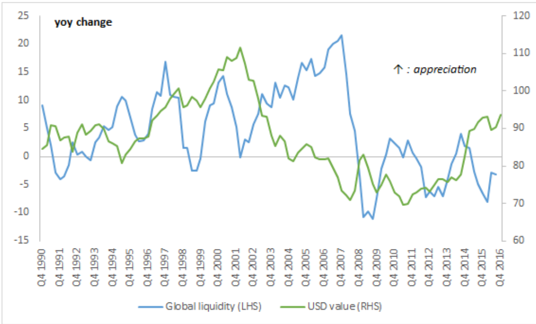
(b) Scatter plots

Figure 5.3: Global liquidity and US policy rate, source: BIS and Datastream.

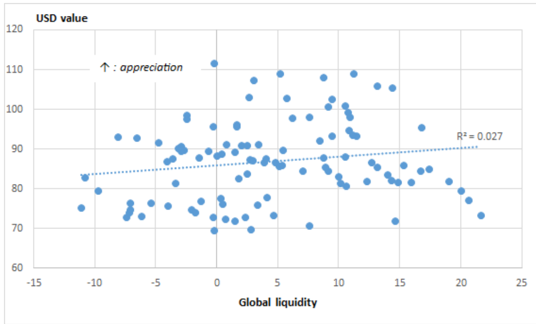
5.4.1.3 US Policy Rate

We include the US monetary policy rate in the VAR model due to the fact that the US Dollar is the most significant international currency used in the global liquidity, which includes US Dollar denominated local lending as well as US Dollar denominated cross-border lending. The value of USD in the global market is significantly determined by the US Federal Reserve monetary policy stance. More importantly, two important channels through which the Federal Reserve aims to influence the real economy, i.e. the monetary policy transmission channel, is through the credit channel and risk-taking channel. We use the US monetary policy rate variables calculated by Wu and Xia (2016) which provides hypothetical US monetary policy rate when it was at the zero lower bound. Figure 5.3a shows the line graphs of the US monetary policy rate and the global liquidity, as well as the scatter plot between the two series.

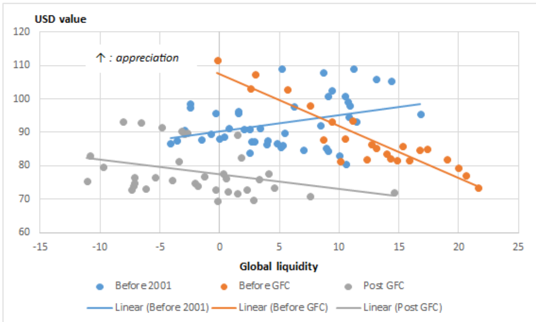
It is surprising that a positive correlation emerges between global liquidity and the US monetary policy rate. We divide the periods into before and after 2004 when the Federal Reserve aggressively reduces policy rate to combat recession. Furthermore, in Figure 5.3b we divide the post-2004 period further into two periods, i.e. before and after the global financial crisis. All scatter plots in various periods suggest a positive correlation between US monetary policy and global liquidity. In other words, a high US policy rate seems to be associated with the boom in the global liquidity, and the other way around.



(a) Global liquidity and US dollar value



(b) Scatter plots

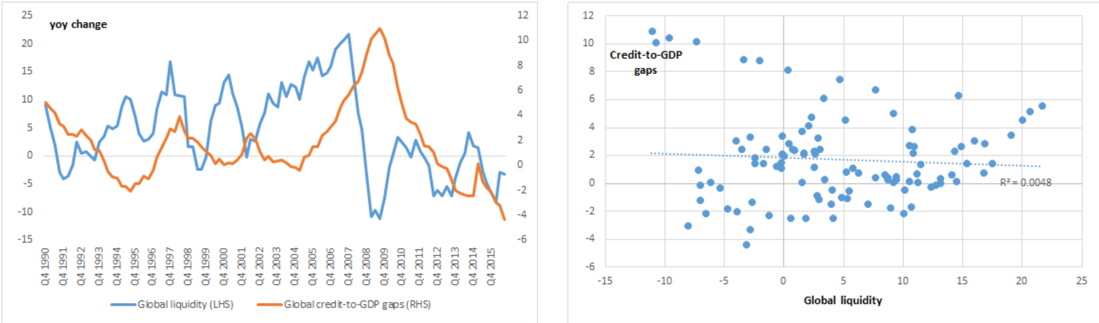


(c) Scatter plots

Figure 5.4: Global liquidity and US dollar value, source: BIS and Datastream.

5.4.1.4 US Dollar Value

The inclusion of US Dollar value in the group of global variables is meant to capture the risk-taking behaviour of banks in the international market. Shin (2016) argues that following a depreciation of US Dollar, there is a tendency of higher cross-border banking lending due to the willingness of foreigners to borrow in the US Dollar. Furthermore, the US Dollar is the highest denomination in the global cross-border banking lending and borrowing. The US dollar value we use is the trade-weighted US Dollar value against a basket of major counterparty currencies from Datastream. An increase in the US Dollar series means an appreciation of US Dollar. The scatter plot of the US Dollar value against global liquidity variable seems to show a small positive correlation. However, a closer look at the scatter plot shows a time-varying correlation. We divide the sample into three periods: (a) before USD deep depreciation starting in 2002 following aggressive US monetary policy accommodation to combat US recession, (b) pre-global financial crisis, and (c) post global financial crisis. In the first period, a positive correlation emerges, while in the following two periods, the correlation becomes negative.



(a) Global liquidity and credit-to-GDP gaps (b) Scatter plots

Figure 5.5: Global liquidity and global credit-to-GDP gaps, source: BIS.

5.4.1.5 Global Credit-to-GDP Gaps

The other variable to include is the global credit-to-GDP gap. The Bank for International Settlements (BIS) provided credit-to-GDP ratio data for each 44 reporting countries. The credit data covers all credit extended to the *private non-financial sector* from foreign and local sources. The credit-to-GDP gap is the difference between actual credit-to-GDP and its long run. The credit-to-GDP long-run trend is calculated using a one-sided Hodrick-Prescott (HP) filter with a lambda of 400,000 by the BIS. The credit-to-GDP gaps series are aggregated using simple average across all reporting 44 economies.

The inclusion of the global credit-to-GDP gap data is as a proxy for bank's capital position and to capture the willingness of the banks to lend to the real sector which represents the perceived global state of the economy and the riskiness. Past studies also show that the credit-to-GDP gap is an important early warning system for the financial crisis as the fluctuation of credit and asset prices indicate the risk-taking behaviour of financial intermediaries. A glance at the line plots of global liquidity and a credit-to-GDP gap against time suggests a small correlation between the two series. However, a closer look suggests that global liquidity fluctuation seems to lead the credit-to-GDP gap fluctuation by six quarters (1.5 years). If the global liquidity plot is led by 1.5 years, its trend matches credit-to-GDP gaps trends quite significantly, and the scatter plots suggest positive correlation between the two series.

5.4.2 Second Set of Analysis: Cross-border Banking Interconnection

5.4.2.1 Countries' Cross-Border Banking Claims and Liabilities

The quarterly data on the total cross-border claims and total cross-border liabilities of banks based on country's location is obtained from Table A5 of the Bank for International Settlements (BIS) Locational Banking Statistics (LBS). The BIS locational banking statistics capture the cross-border claims and liabilities position of internationally active banks located in reporting countries, including the offshore financial centres, against counterparties residing in more than 200 countries. The recording of the cross-border positions follows the principle of balance of payment statistics. The total international banks' positions reported in the locational banking statistics makes up around 95% of all cross-border interbank business across the globe.

Table A5 in BIS locational banking statistics shows the cross-border claims and liabilities positions of banks based on the location of the reporting banks, not on the residency of the banks. As a result, Table A5 records all cross-border banking flows, even if the banks are of the same holding. For example, the lending Deutsche Bank's headquarter in Germany extends to its affiliate in the UK is recorded in the BIS locational banking statistics.

The total cross-border *claims* data for each reporting economy includes all international claims to all other economies, all counterparty's sector, all instruments, and all currency. The same also applies to cross-border *liabilities*. As the data for GVAR analysis requires full sample set for each series and reporting countries started to supply the data to BIS differently, there is a trade-off between the number of economies and the length of time series to be included in our analysis. As a result, we started the cross-border banking claims and liabilities data from the fourth quarter of 2003 to include as many economies as possible, especially emerging economies which mostly started reporting to BIS a lot later than most advanced economies. The data ends at the third quarter of 2016, which makes a time series in our data consists of 51 points of time only. The data covers 35 economies' data which includes ten advanced economies, eleven Euro economies, five emerging economies, and nine offshore financial centres.

Figure 5.6 shows the evolution of cross-border net claims positions of each country from 2003 to 2016. The graph shows that international banks located in Japan in aggregate continuously increased their cross-border lending even after the 2007/08 global financial crisis, which makes Japan the most important banking lenders in the world. The same position as the most

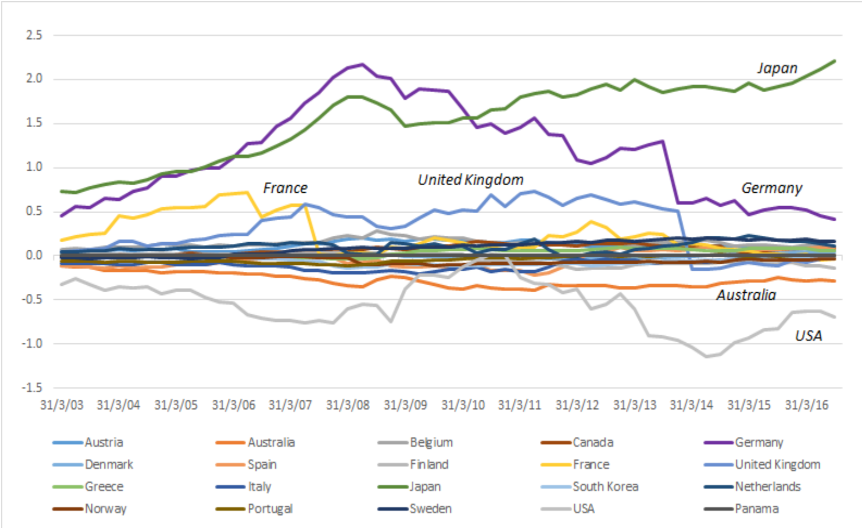


Figure 5.6: Cross-border banking position, by reporting country, advanced economies, in USD trillions

important bank lender also applies to Germany but only until the global crisis, because after the crisis Germany's position as net lenders continued to decrease significantly. The peak net international lending positions by the German banks was USD 2.2 trillion in the second quarter of 2008, but the position continued to decline to USD 0.4 trillion in the third quarter of 2016.

The banks located in the USA as an aggregate has always been the net borrowers globally, although the net borrowing positions fluctuated with net borrowing of a maximum USD 1.1 trillion in the third quarter of 2014. Although the UK has the most international banking positions in terms of the absolute total of international claims and liabilities, the UK has never had the most net borrowing positions nor lending positions in the world. This shows that the banks located in the UK in aggregate have functioned as the most important financial intermediation hub across the globe, but do not take a particular position in national aggregate level as either the largest funding liquidity provider nor largest recipient.

Figure 5.8 shows the evolution of the cross-border banking positions of international banks located in emerging economies. It is apparent that all emerging economies in the sample have been the net borrowers in most of the data periods. The amount of net borrowings of the banks in emerging economies continues to increase even after the onset of the global financial crisis. Among the emerging economies, the net borrowings position's trend in India and Turkey are the steepest.

The bar chart in Figure 5.9 shows the total of claims and liabilities in absolute terms for

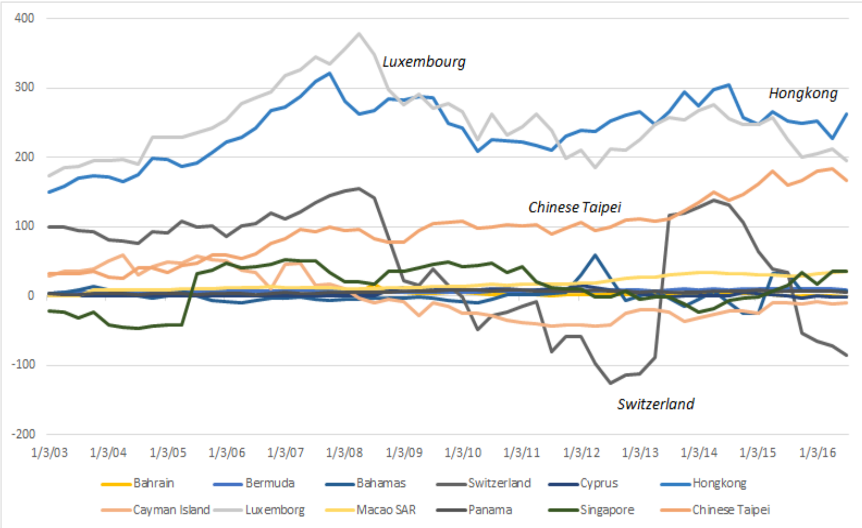


Figure 5.7: Cross-border banking position, by reporting country, offshore financial centres (according to IMF classification), in USD billions

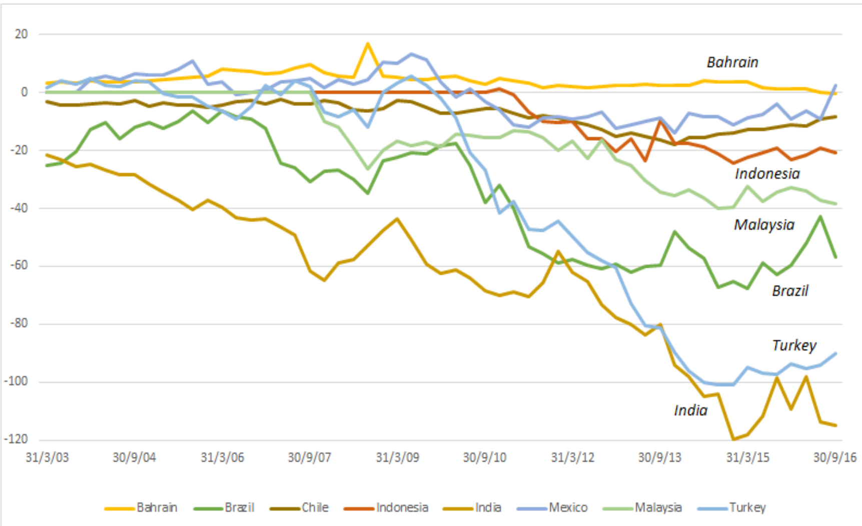


Figure 5.8: Cross-border banking position, by reporting country, emerging economies (USD billions)

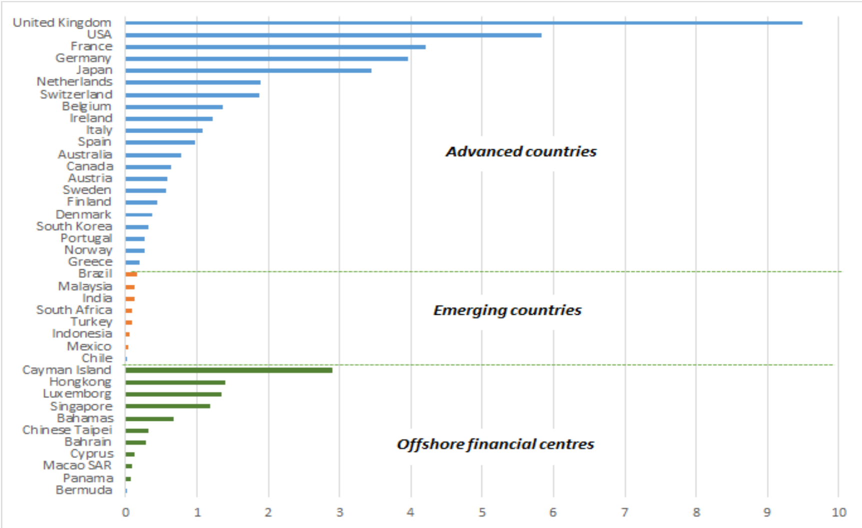


Figure 5.9: Cross-border banking position in absolute term (claims + liabilities), average between 2003 to 2016, in USD trillion

each country, averaged over the first quarter of 2003 to the third quarter of 2016. The bar chart is intended to compare the magnitude of overall banking activities, i.e. borrowing and lending, across countries. The upper, middle, and lower part of the bar chart are classified as advanced economies, emerging economies, and offshore financial centres, respectively. The chart shows that the cross-border positions of international banks operating in the advanced economies are far larger than the emerging economies as well as offshore financial centres. More surprisingly, the absolute cross-border positions of many offshore financial centres like the Cayman Islands, Hong Kong, Luxembourg, Singapore, and the Bahamas are also far larger than all emerging countries. This shows the importance of the tax haven destinations in providing global financial hub services for major financial intermediaries across the world.

The chart shows that the UK has the largest global banks cross-border positions in absolute terms in the world. Although the UK cross-border net positions have never been significantly positive nor negative compared to other advanced economies like Germany, the US, or Japan, the large absolute total positions show that the UK as the most important financial centre in the world. The UK's absolute cross-border banking position on average from 2003 to 2016 stood up to USD 9.5 trillion, almost doubled than USA's average position which was USD 5.7 trillion.

Figure 5.10 shows the average of net claims of cross-border positions for each economy in the sample. The quarterly net claims data is obtained from the total cross-border claims subtracted by the total cross-border liabilities from BIS locational banking statistics. We take

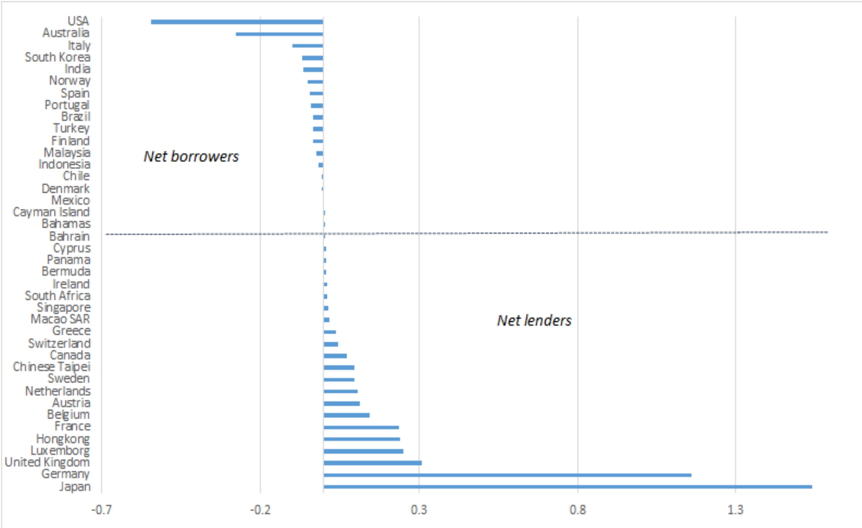


Figure 5.10: Cross-border net claims banking position, average from 2003 to 2016, by reporting country (USD trillion)

a simple average of the net claims positions over the periods from 2003 or whenever the data become available for each economy, until the second quarter of 2016. Taking the average across 51 quarters (13 years) periods, the graphs show that the United States, Australia, and Italy are the largest net borrowers in the world. This means that in aggregate the banks located in the three economies hold the largest net liabilities international positions in the world with USD 550 billion, USD 280 billion, and USD 100 billion net borrowings positions, respectively, as an average throughout the past thirteen years period. Japan, Germany, and the UK are the largest net lenders with the amount of cross-border net lending positions of USD 1.5 trillion, USD 1.2 billion, and USD 250 billion respectively.

Figure 5.11 and Figure 5.12 divide Figure 5.10 into net borrowers and net lenders only. The bar chart for advanced economies is in blue, emerging economies in orange, while offshore financial centres in green. The figures show that some advanced economies are net borrowers, while some others are net lenders. Almost all emerging economies are net borrowers, whereas most of the offshore financial centres are net lenders. The most important offshore financial centres with the largest net lending positions are Luxembourg, Hong Kong, and Chinese Taipei with average net lending positions of USD 230 billion, USD 220 billion, and USD 100 billion respectively.

The largest net borrowers from the emerging economies group are India, Brazil, and Turkey with average net borrowing positions of USD 70 billion, USD 40 billion, and USD 38 billion respectively. This shows the importance of the global banks' activity in extending funding

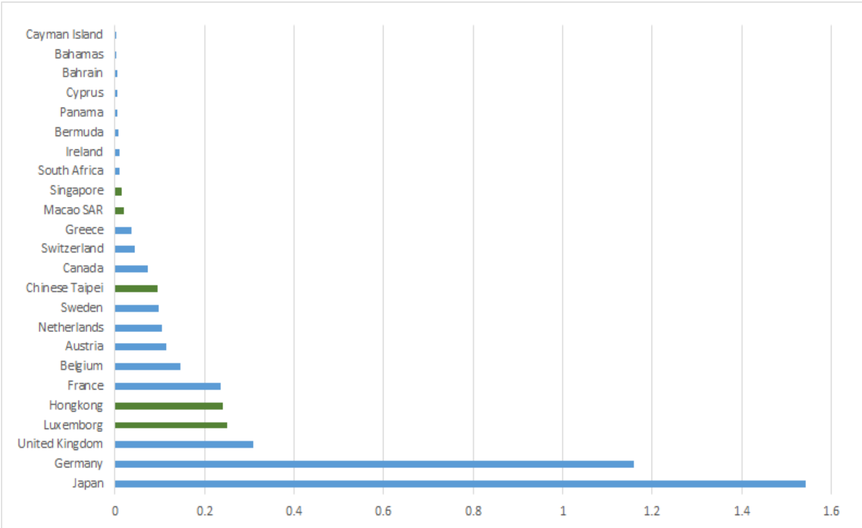


Figure 5.11: Cross-border banking position, by reporting country, average between 2003 to 2016, net lenders only (USD trillion)

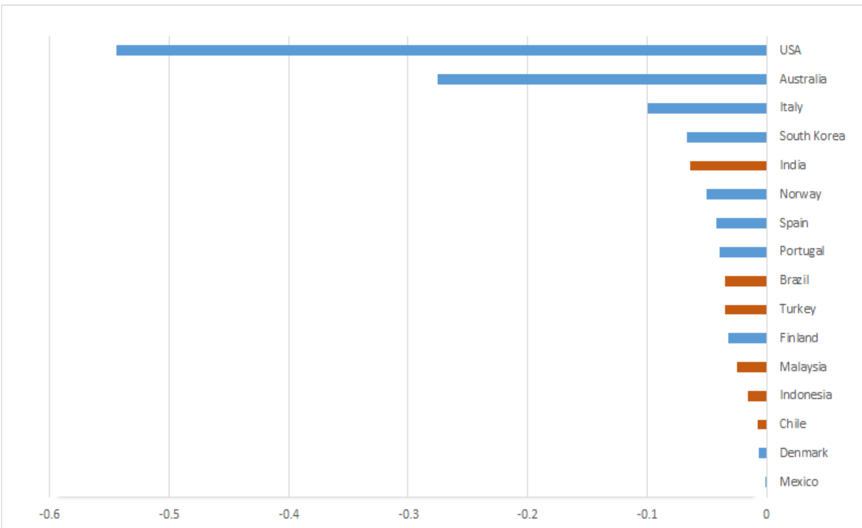
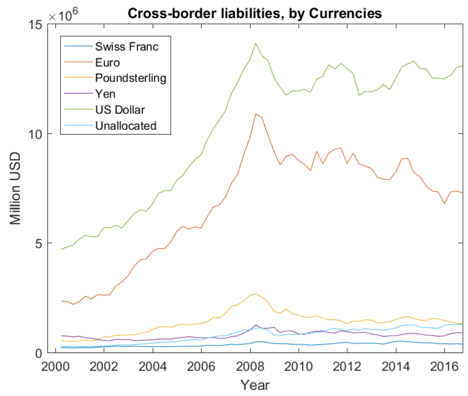
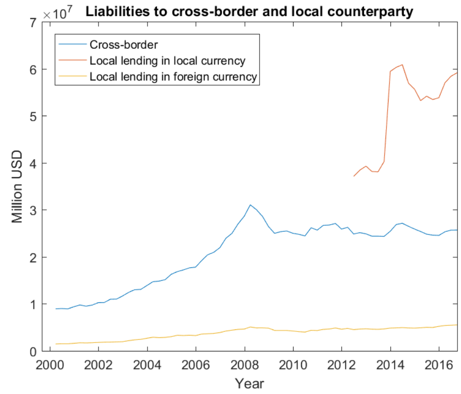


Figure 5.12: Cross-border banking position, by reporting country, average between 2003 to 2016, net borrowers only (USD trillion)



(a) Global cross-border lending, by currency



(b) Global cross-border and local lending, by currency

Figure 5.13: Global cross-border and local banking lending, by currency. Source: BIS, Locational Banking Statistics.

liquidity to banks located in emerging economies. In terms of magnitude, the cross-border banking positions of most advanced economies are far larger than the cross-border positions of banks in emerging economies. The unbalanced nature of cross-border magnitudes between the two groups of economies makes the banking activity in the emerging economies much more susceptible to changes in international positions of advanced economies' banks' positions in emerging economies' banks. In other words, because the national capacity of emerging economies banks is small, a cross-border position change that is considered small by an advanced economies' banks can be very significant by an emerging economies' banks.

By currency, the US dollar is the most important currency for cross-border banking activities with a total of USD 13 trillion of cross-border bank activities in the second quarter of 2016 as shown in Figure 5.13a. The Euro was almost as important as the US Dollar for the periods up until the 2007-08 global financial crisis. Following the crisis, lending in the Euro decreased steadily and currently, it is used in USD 7 trillion worth of cross-border banking activities which is only a little more than half of the portion of cross-border banking denominated in the US Dollar. The decreasing trend of Euro-denominated cross-border lending is consistent with a decreasing trend of Germany's banking lending activities.

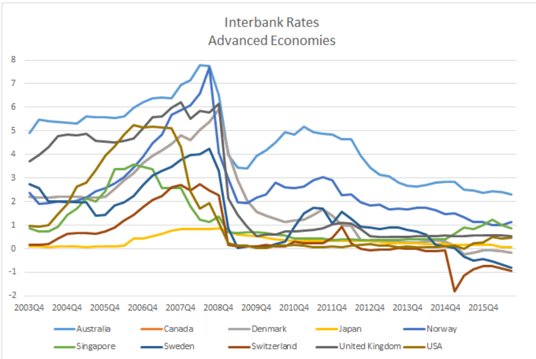
As shown in Figure 5.13b cross-border lending is distributed mostly in foreign currencies, whereas local lending is apparently dominated by local currency denomination with USD 60 trillion lending globally. There is also, however, a small portion of local lending (i.e. made by local banks to local borrowers) that are denominated in foreign currencies, which is accounted for USD 0.5 trillion globally in the second quarter of 2016. The 'global liquidity' figure that we discuss in Section 4.1 consists of these two figures, i.e. cross-border lending and local lending in foreign currency.

5.4.2.2 Interbank Market Rates

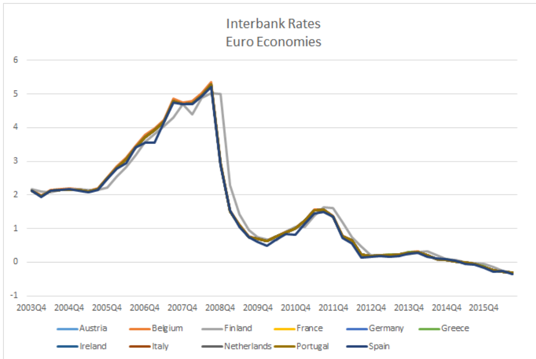
The interbank market rates series are quarterly 3-month interbank offered rate data for each economy from Datastream. The series are considered as proxies for the banking funding liquidity. The average of interbank market rates across all economies in the sample is 2.4 with maximum 6.3 and minimum 0.1. The measure of skewness shows that interbank market rates for most economies are positively skewed with an average skewness magnitude of 0.7 indicating that rates are lower than the median in most periods of data. Put differently, higher interbank rates are rarer than lower rates. The measure of kurtosis for most economies is less than 3 with the mean of 2.5 across all economies which indicates fat-tailed distributions, i.e. outliers are more common in this series' distribution compared to normal distributions.

Figure 5.14 plot the interbank market rates according to its groups of economies. The graphs show the relative synchronization of interbank market rates in advanced economies, particularly in the run-up and after the 2007-08 global financial crisis. For this group of economies, Australia in general has the highest interbank rates with a mean of 4.6 whereas Japan's interbank rates are the lowest with the average of 0.3. The emerging economies' interbank rates do not seem as closely synchronized, which indicate weaker inter-linkages of banking sector cross-border activities among the economies in this group. From economies that are categorized as offshore financial centres, only Hong Kong that owns an interbank market, since all other offshore financial centres are small jurisdictions and thus have no large banking sectors.

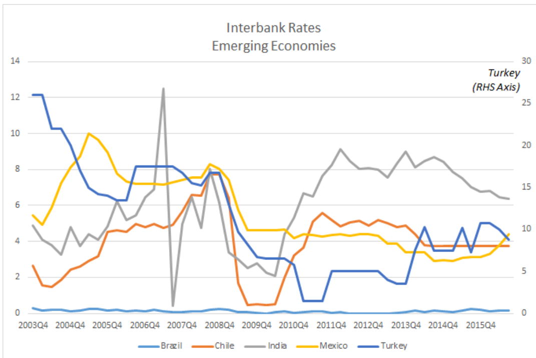
For the Euro Area countries, the individual countries' interbank rates are merged to Euribor since January 1999 except for Greece's interbank rate that merged to Euribor in January 2001. Thus, the interbank market rates for the Euro area countries which are included in this study is almost identical throughout the period of study from 2003 to 2016.



(a) Advanced economies



(b) Euro economies



(c) Emerging economies

Figure 5.14: Interbank market rates, by group of economies. Source: Datastream.

5.4.3 Bilateral Consolidated Positions

The GVAR model requires a weighting matrix to establish 'foreign' variables for each economy in order to solve the dimensionality problem. The matrix maps out the strength of connectivity across economies, allowing the estimation of the impact of any foreign variable changes to the domestic economy model. The weighting matrix can be built using any measurement of bilateral relationships between each pair of economies, which describes the relative strength of connection of every pair of economies.

We use the BIS consolidated banking statistics to build our weighting matrix. The BIS consolidated banking statistics capture the worldwide consolidated positions of internationally active banking groups which are headquartered in reporting countries. Like the BIS locational banking statistics, the BIS consolidated banking statistics is also reported on an aggregated (nation-wide) basis, rather than individual banking level. The difference between the locational and consolidated banking statistics is that, the BIS consolidated banking statistics considered one banking holding as one entity even if they are located in different jurisdictions. Thus, the consolidated banking statistics does not include cross-border lending and borrowing within one bank holding.

The BIS consolidated banking statistics is designed to measure the international exposures of internationally active banks of different nationalities, arising from their lending to various countries and sectors. One example of the international exposures is the inability of foreign borrowers to pay back the lending extended by the international bank in its headquarter, as well as its affiliates located in the other economy. Although the main purpose of the consolidated banking statistics is to measure the global exposures of internationally active banks, the statistics can also be used to measure risks faced by emerging economies of the reversal of international funding liquidity provided by international banks. Moreover, from the point of view of a country, the magnitude of foreign lending provided by international banks to its local banks not only determines the reversal risks but also provides international spillover funding liquidity channel from the country where the international banks' headquarter is located. Risk-taking channel of cross-border monetary policy spillovers can potentially work through this international bank lending.

Figure 5.29 shows the weighting matrix that we build from the consolidated banking statistics. The banking statistics measure cross-border position from one side only, which is *claims* to other economies, instead of liabilities. The economies in each row are the nationalities of the international banks that have foreign claims on banks located in economies in each column. Thus, in aggregate national terms, the foreign banking lending goes from economies in each row to economies in each column. The order of the country is sorted by their importance in global financial markets, therefore most advanced economies are in the most left and top order. The blue and red colour in each cell represents the relative magnitude of bilateral cross-border positions of the pair of economies, where blue colour represents larger and red represents a lower magnitude of cross-border positions. In relative terms, the magnitude of cross-border banking positions is very high in the top left corner of the table suggesting that the global banking flows are dominated by the advanced economies, in particular USA, UK, Germany, and Japan. The red cells which are dominant on the table indicate that most pairs of economies have relatively low cross-border positions, compared to the cross-border positions of a few major economies. In other words, the distribution of the cross-border positions is very much skewed to the left. Some economies with blank rows are non-reporting BIS consolidated banking statistics economies. One of the reason for an economy not being a reporting economy is because it does not have an internationally active bank headquartered in its jurisdictions. These economies only have international banking liabilities arising from international lending from banks in advanced economies, but do not have international banking claims.

5.5 First Analysis Results: Global Liquidity Determinants and Relationship with the Other Variables

In order to study the potential major determinants of the global liquidity and how the global liquidity interacts with the other global variables, we perform a VAR to the global liquidity, US policy rate, trade-weighted US Dollar value against major trading currencies, global credit-to-GDP gaps, and TED spread. We include four lags of every variable into the VAR system due to the quarterly frequency data. The lower and upper confidence band of the point estimate is obtained by bootstrapping method of 1000 draws with 90% confidence band.

Figures 5.15 to 5.19 show the generalized impulse response function (GIRF) graphs of the VAR system. In general, the GIRFs show that the shocks to all selected global variables, i.e. US monetary policy rate, US Dollar value, global credit-to-GDP ratio, and TED spread are significant for the global liquidity variable. On impact, the effect of the increase in the US

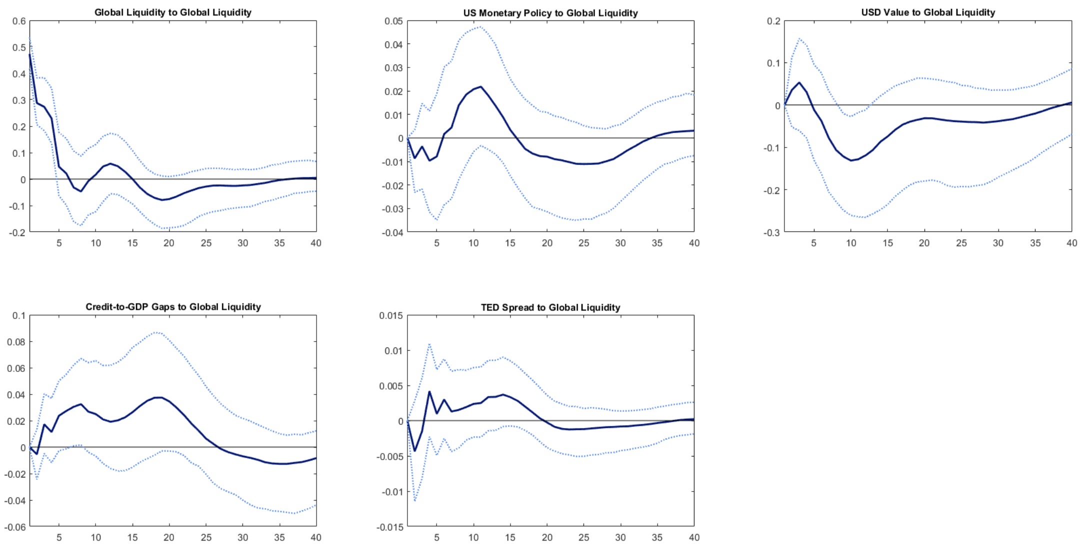


Figure 5.15: GIRFs of global variables from 1 SD shock to global liquidity

policy rate and global credit-to-GDP gaps is to increase global liquidity (Figures 5.16 and 5.18). On the other hand, the effect of positive shocks to the US Dollar value (USD appreciation) and TED spread (Figures 5.17 and 5.19) is to decrease global liquidity. Most of the effects are significant and reach its maximum in around 1 to 1.5 years.

Figure 5.15 shows the generalised impulse response functions of the global variables from a positive standard deviation shock to the global liquidity variable. The GIRFs demonstrate that the effect of positive global liquidity shocks is slightly negative on the US monetary policy rate in the short run and positive in the medium run (although the impact is not highly significant); negative on USD value in the medium run (positive in the short run); positive on global credit-to-GDP gaps and the TED spread. Higher cross-border banking lending as indicated by a positive shock in the global liquidity variable apparently increases global credit extension to the private non-financial sector and the effect remains significant in the short and medium term. The USD depreciation following higher global liquidity in the medium term suggests that cross-border banking liquidity is dominated by capital outflows from the US banking system. The higher US policy rate implies the US Federal Reserve tightening policy to contain future inflationary pressure following higher credit extension.

A positive standard deviation shock to the US monetary policy rate has large positive effect on global aggregate cross-border lending on impact with maximum effect in 1.5 years (Figure 5.16). However, the effect becomes negative in around 2.5 years. This increase in the

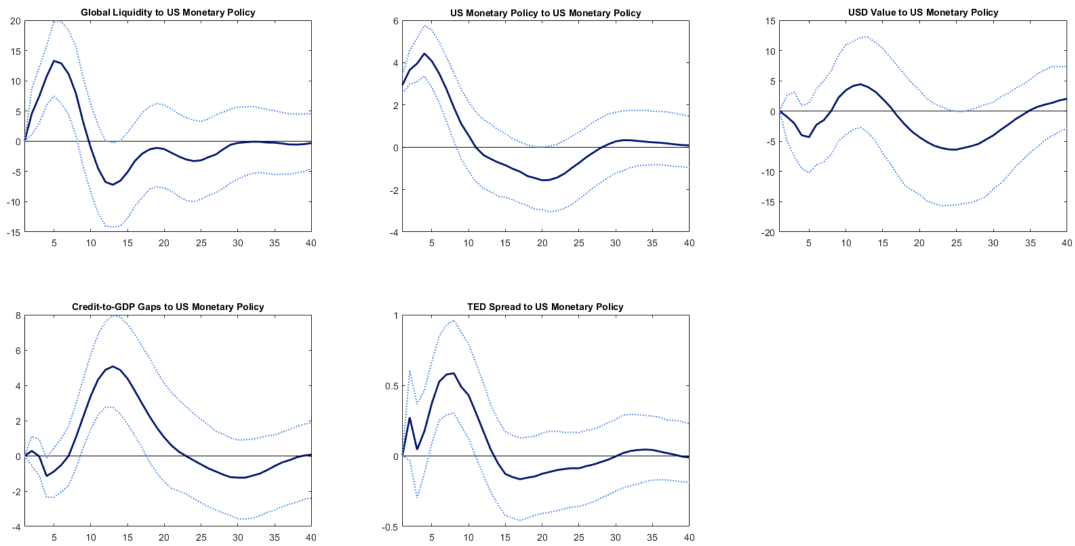


Figure 5.16: GIRFs of global variables from 1 SD shock to US monetary policy

global liquidity seems to be dominated by higher cross-border banking lending to US banking system following higher US interest rate expectation. This conjecture is supported by the USD appreciation in the medium term following the same positive US policy rate shock, although the appreciation is not significant. The effect of positive US policy rate shock is positive on the TED spread indicating the tightening of the cross-border interbank funding liquidity condition. The tightening of the interbank funding liquidity condition reduces the global credit extension to private non-financial sectors as shown by lower credit-to-GDP gaps, although the immediate impact is not significant. Interestingly, in the medium term (2 to 4 years) the US policy rate shocks affects the global credit extension to the non-financial sector positively, possibly due to the loan supply effect as banks expect a higher return from lending.

Figures 5.17 show that on impact the global liquidity is affected negatively by a positive shock on the USD value against major trading partners (i.e. USD appreciation) and the effect is quite significant for around 1.5 years. This seems to suggest that a USD depreciation causes global liquidity to increase, which supports the international transmission of 'risk-taking channel' where a cheaper dollar tends to cause international banks to take more risk and, thus, lend more. This is also supported by the global credit-to-GDP ratio response to USD shock, where the effect of a negative shock on the USD value (a USD depreciation) is positive and significant to the global banking credit disbursement to non-financial sectors across the globe. This evidence also underlines the importance of USD value as the most important global

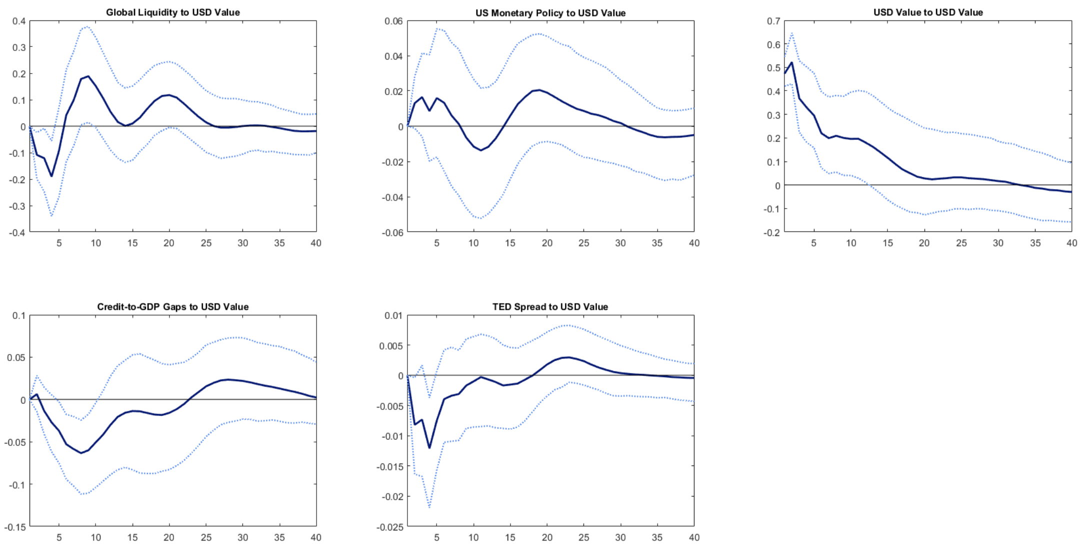


Figure 5.17: GIRFs of global variables from 1 SD shock to US Dollar value

reserve currency in the 'risk-taking channel'. There is also a strong negative response in the TED spread to the USD appreciation shock, which seems to indicate that stronger dollar reduces the tightness of interbank market borrowing and lending and the effect is persistent until around three years after the impact.

Figures 5.18 show the impulse response functions of global variables associated with a positive standard deviation shock to the global credit-to-GDP gaps. The global credit-to-GDP gaps is a proxy for global banks' capital position and their willingness to take risks from lending to the non-financial sector. Obviously, higher global credit extension is associated with higher global cross-border banking lending and the effect is significant on impact for around 2 years after the shock. The positive shock to global credit has negative effect on USD value (a USD depreciation) quite significantly in the short to medium-term. An increase in the global credit-to-GDP gaps reflects an international loan demand shock which induces higher demand for global liquidity, which then leads to USD depreciation as capital outflows from the US economy emerge. However, the shock to global credit-to-GDP gaps does not seem to affect US monetary policy and TED spread significantly.

Figures 5.19 show the dynamic impact on global variables following a positive standard deviation shock to the TED spread. The TED spread variable is a proxy for credit risk of the counterparty, where larger TED spread indicates higher credit risk and thus tighter interbank market condition. There is a significant decrease in the global liquidity to a positive shock

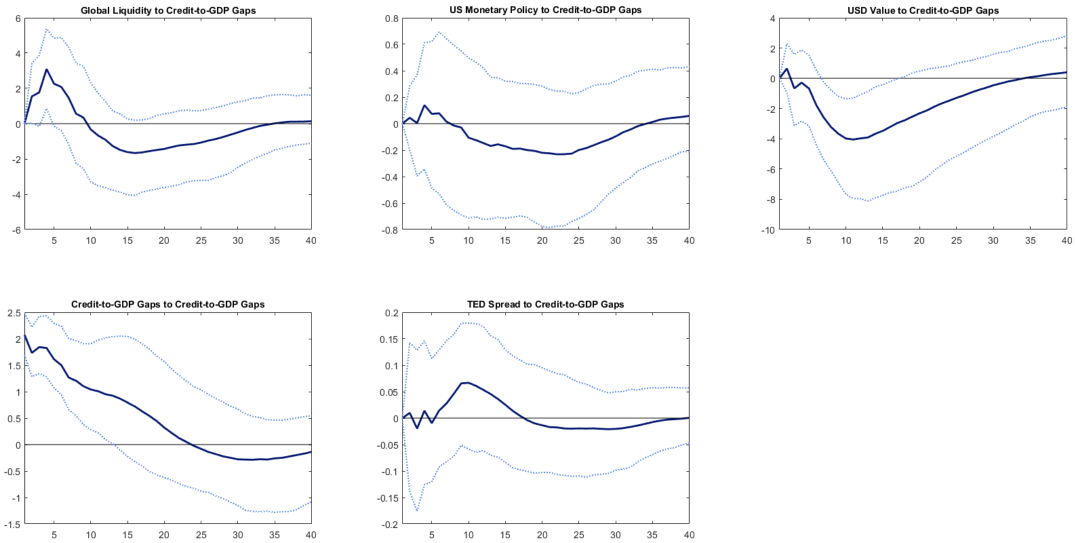


Figure 5.18: GIRFs of global variables from 1 SD shock to global credit-to-GDP ratio

to TED spread. This suggests that a higher perception on counterparty banks' credit risks is associated with a significant reduction in the cross-border banking lending internationally with the strong effect remaining until around 2 years post the shock. The tighter global interbank condition appears to cause the Federal Reserve to accommodate the US monetary condition by lowering the policy rate, although the effect is not significant. The effect of a positive TED spread (an increase in the perceived credit risk in the banking sector) is to increase USD value suggesting an increase demand for the USD as the safe haven currency, although the effect is significant only in 4 quarters.

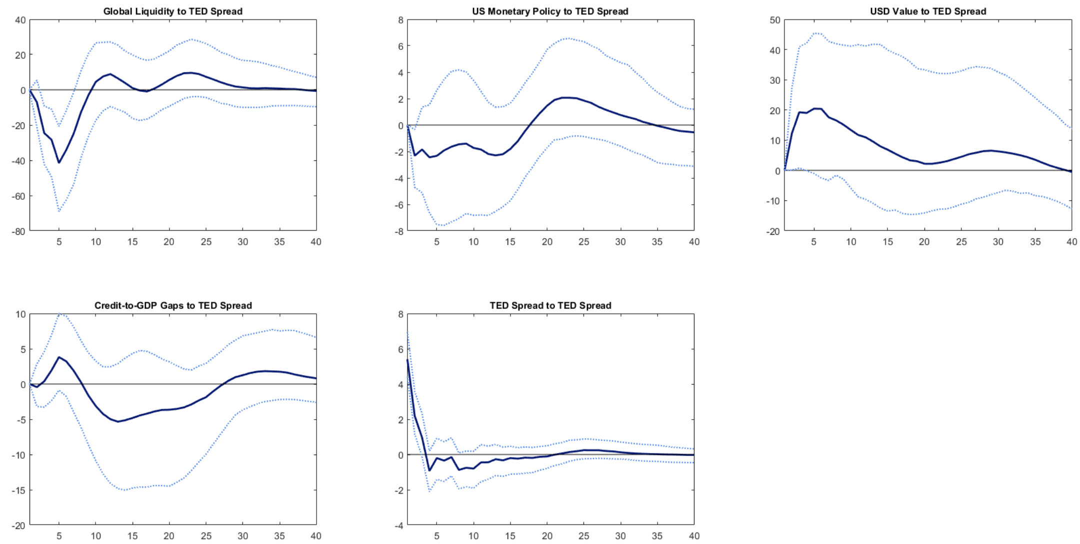


Figure 5.19: GIRFs of global variables from 1 SD shock to TED spread

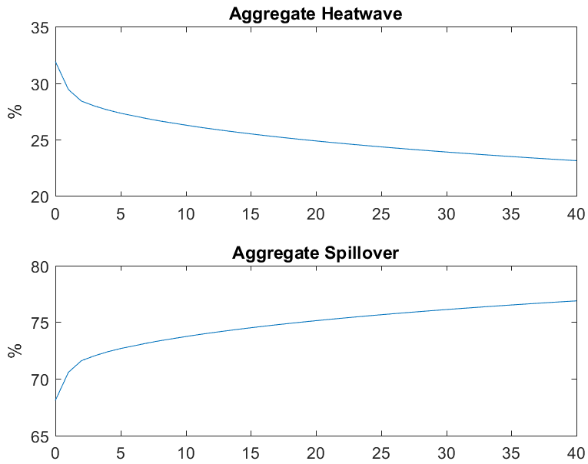


Figure 5.20: Heatwave and spillover, aggregated globally across all economies

Note: The measurement is percentage such that for every forecast horizon, the aggregate heatwave and aggregate spillover adds up to 100 per cent.

5.6 Second Analysis Results: Measuring the Connectedness of Banking Liquidity in the Global Economy

To study the international spillovers of the banking liquidity, first, we perform the GVAR on the cross-border claims and liabilities, and interbank market rates of the 35 countries in our dataset, including three global variables (i.e. global liquidity, US monetary policy, and US Dollar value). The estimates from the GVAR are then used to produce the Generalized Forecast Error Variance Decomposition (GFEVD) of shocks to each of the variables on the horizon of 40 quarters. The GFEVD shock is presented as a three-dimensional array where the first dimension lists every variable in every economy where the shock is from, the second dimension lists to which variables the shock is to, and the third dimension contains the full 40 forecast horizons. For every horizon, the main diagonal element represents the *heatwave* effects, whereas the off-diagonal elements show *spillover* effects. The three-dimensional GFEVD array is then utilized to build the various connectedness measure as in (Diebold and Yilmaz, 2009; Diebold and Yılmaz, 2014; Greenwood-Nimmo et al., 2015a,b).

Figure 5.20 shows the systemwide *heatwave* and *spillover* effects that are calculated by aggregating the effects across all variables of all economies in the dataset as shown in equation 5.24 and equation 5.25. The aggregate heatwave and spillover effects are plotted against the forecast horizons to observe how the effects evolve throughout the forecast horizons.

The notable observation from the two graphs is that in aggregate the *heatwave* effects recede with the forecast horizon while the *spillover* effects tend to grow over the forecast horizon. The observation that global spillovers intensify over time suggests that the international transmission of shocks occurs gradually, replacing some part the impact coming from the domestic economy. The second observation is that, the globally aggregated spillover is greater in magnitude compared to the aggregate heatwave, as the spillover effect comes from every other country in the system. Figure 5.21 disaggregates the systemwide heatwave effects into each economy's heatwave effects, shown by the shaded area in the subfigures. It is the *within* country connectedness ($H^{(h)}_{j \leftarrow j}$) across horizons. When disaggregated across different economies, it is shown that most of the heatwave recede over time (as it is the case in the aggregate heatwave). The heatwave effects appear to be stronger in many offshore financial centres like the Bahamas, Bahrain, and Taiwan.

Figure 5.22 shows the *spillover* effects of each economy which are plotted through forecast horizon. Unlike the *heatwave* effects that are focused on the impact of shocks within one economy, the *spillover* impact measures the implication of shock to one economy on the rest of economies in the system. For each subfigure containing the j-th country, the *from* contribution ($S^{(h)}_{j \leftarrow \bullet}$) is plotted as blue line, whereas the *to* contribution ($S^{(h)}_{\bullet \leftarrow j}$) is plotted as red line. The *from* contribution measures the total spillover from all other economies to economy j (i.e. the total *from* contribution affecting economy j), whereas the *to* contribution measures the total spillover to all other economies from economy j (i.e. the total *to* contribution arising from economy j). The *net* connectedness is shown by the shaded region.

In the large majority of cases, the *net* connectedness of the k-th economy does not change sign over the forecast horizon. This implies that the choice of forecast horizon is unlikely to change our results decisively. In most cases, the net connectedness of the countries is positive suggesting that the banking condition of these countries are more likely to receive shocks from foreign banking condition than to influence them. The net connectedness measurement is negative for the USA and global variables only, which means that the cross-border claims and liabilities, and interbank rate in the USA, as well as the global variables (global liquidity, US monetary policy, and US Dollar value), are significant in influencing the global cross-border banking activities. For some countries, the net connectedness is almost zero throughout the forecast horizon, implying that their degree of influence to other economies is almost as large as the influence they receive from outside banking condition. Including in these group are

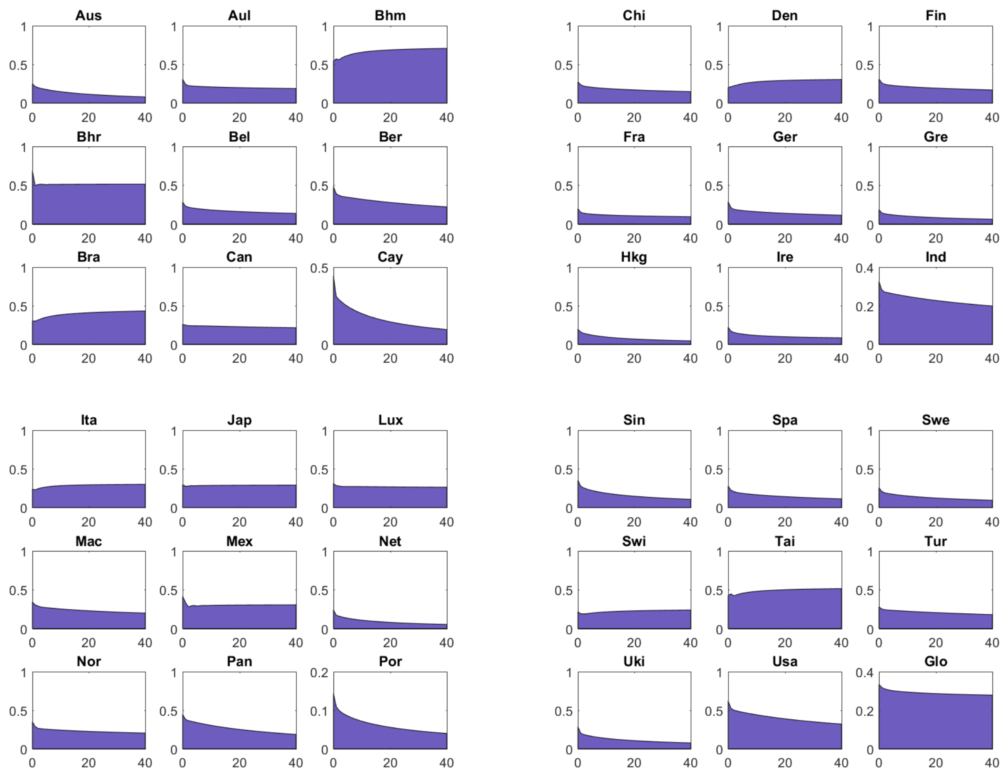


Figure 5.21: Time-varying heatwave for each economy, for horizon up to 40 quarters

Note: Aus: Austria, Aul: Australia, Bhm: the Bahamas, Bhr: Bahrain, Bel: Belgium, Ber: Bermuda, Bra: Brazil, Can: Canada, Cay: Cayman Islands, Chi: Chile, Den: Denmark, Fin: Finland, Fra: France, Ger: Germany, Gre: Greece, Hkg: Hongkong, Ire: Ireland, Ind: India, Ita: Italy, Jap: Japan, Lux: Lumbeourg, Mac: Macao SAR, Mex: Mexico, Net: the Netherlands, Nor: Norway, Pan: Panama, Por: Portugal, Sin: Singapore, Spa: Spain, Swe: Sweden, Swi: Switzerland, Tai: Taiwan SAR, Tur: Turkey, Uki: the United Kingdom, Usa: the USA, Liq: global liquidity

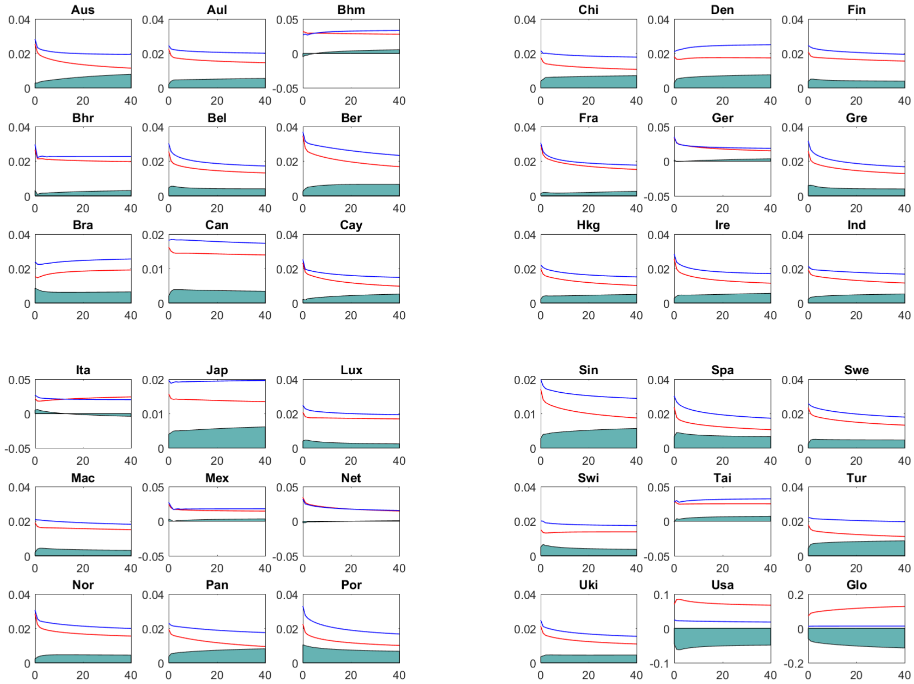


Figure 5.22: Time-varying connectedness for each economy, for horizon up to 40 quarters

Note: Blue line plots the *from* contribution, red line plots the *to* contribution, and the shaded region shows the *net* connectedness.

economies with important international banking presence i.e. France, Germany, Italy, and the Netherlands; some offshore financial centres i.e. the Bahamas, Bahrain, and Taiwan. The only emerging country that has almost the same *from* and *to* influence is Mexico.

In Figure 5.23 we present the heatwave and spillover effects in a heatmap presentation which presents the heatwave for each economy together with the spillover effects along the pair of economies. The heatmap presentation shows a matrix of connectedness of pair of economies that are averaged across the full horizons. The strength of connectedness between the pair of economies is represented by the colour of the heatmap boxes, i.e. the darker the colour the stronger the connection is. Each box represents the strength of impact *from* the economy listed in the rows, *to* the economy listed in the columns. The row-wise list presents the economies where the shock comes *from*, whereas the column-wise list presents the economy where the shock is directed *to*.

The main diagonal elements of the matrix presents the *within* connections for each economy, i.e. the impact from shocks that coming from domestic variables (e.g. claims, liabilities, or interbank market rates) within a country back to the same country. The heatmap shows

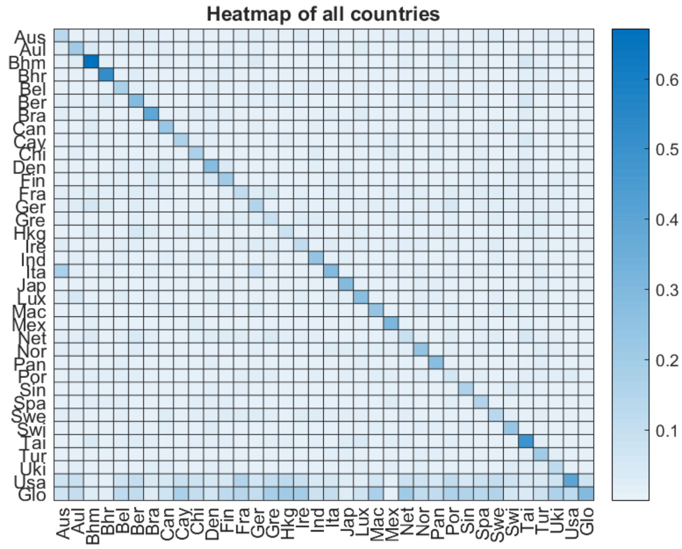


Figure 5.23: Heatmap presentation of all economies

Note: Row-wise lists the economies where the shock *from*, while the column-wise lists where the shock goes *to*.

an obvious darker colour for within connections compared to the rest of boxes, implying that, shocks from variables in the domestic economy are still more important to each country than any foreign variables. The within connections appear to be stronger in the offshore financial centre such as the Bahamas, Bahrain, and Taiwan. Another observation is that, the effect from the global variables (which contain the global liquidity, US monetary policy, and US Dollar) dominates the spillover effects to the rest of economies, implying that shocks from global variables are likely to be the second important foreign impacts to each economy. The next important shocks are coming from the USA.

We then group the economies into four different groups of economies, i.e. the advanced, the Euro, emerging economies, and the offshore financial centres; and one separate group for the global variables. By grouping the economies we can observe a typical pattern of the groups and how each group is connected to every other group. The economies' matrix connectedness is aggregated for each different group of economies as shown in Figure 5.24. As in Figure 5.23, the rows show which groups of economies the shocks are from, while the columns show which groups of economies the shocks affect to.

A few observations emerge here. First, the shocks from the global variables dominate the whole system as the row belong to the global variables group are significantly darker and larger in magnitude. Global variables shocks are even larger compared to the *within* economies'

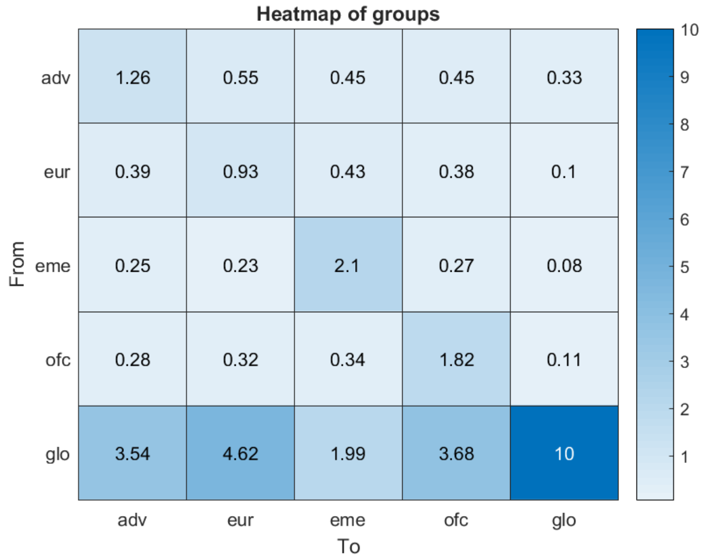
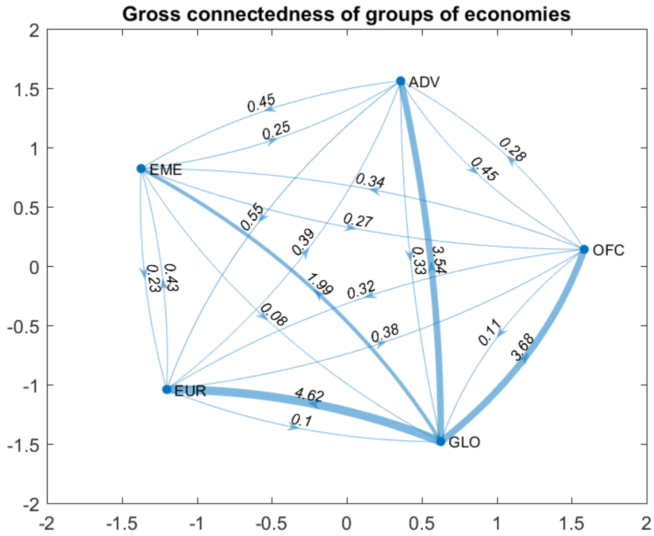


Figure 5.24: Heatmap presentation of groups of economies

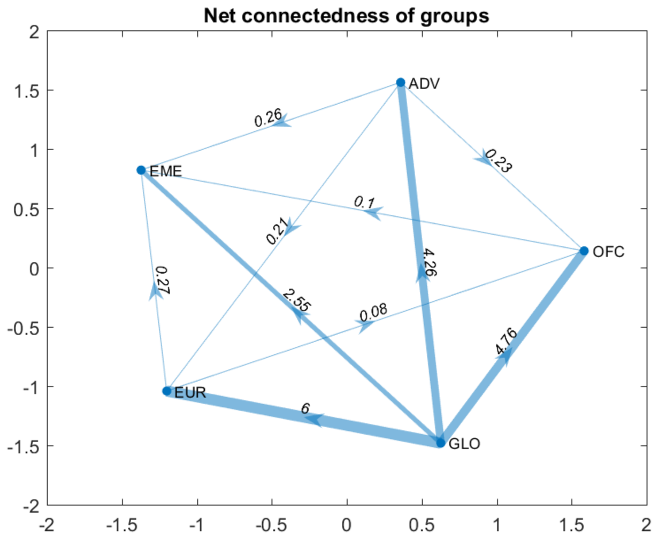
Note: The numbers shown in each box are the connectedness magnitudes averaged across all forecast horizons. The magnitudes are resized such that the largest connectedness magnitude in the heatmap is 10, which happens to be the within shock of the global variables.

shocks (as presented in the main diagonal elements of the matrix) for every group of economies, except the emerging economies. The global banking in the advanced economies group appears to be the second important group with the magnitude of influence to the cross-border banking position in other groups ranging from 0.33 to 0.55. The advanced economies group appears to influence the Euro economies group more than others. The global banks located in the Euro area is the next influential group, affecting mostly to emerging economies, then the advanced economies. The global banks located in the emerging economies do not seem to be influential for the banking condition in the other groups, but they receive influence mostly from the global variables (with magnitude 1.99), the global banks in the advanced economies group (0.45), then from the Euro area (0.43), and the offshore financial centres (0.34).

Figure 5.25a present the connectedness matrix of groups of economies in a directed graph of gross connectedness. Every node represents a group of economies. Every pair of nodes representing a pair of economies' groups is connected with two edges with arrows that show the direction of the connection. The figure is simplified further by presenting only the *net* connectedness between a pair of nodes, as in Figure 5.25b. The figure shows that, from all pair of connections in the system, the strongest impact is the impact of shocks from the global variables to the Euro countries, followed by the shock from the global variables to the offshore



(a) Gross connectedness of groups



(b) Net connectedness of groups

Figure 5.25: Directed graphs representing the connectedness of cross-border banking positions across groups of economies.

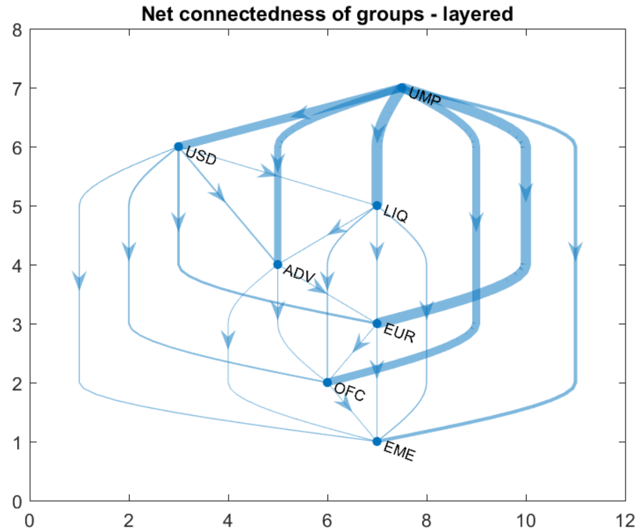


Figure 5.26: Directed graphs representing the connectedness of cross-border banking positions across groups of economies.

Note: UMP: US monetary policy, USD: US Dollar value against major trading partner, LIQ: global liquidity, ADV: advanced economies group, EUR: Euro economies group, OFC: Offshore financial centres group, EME: emerging economies group.

financial centres, and the advanced economies group. Between the advanced and Euro area, the magnitude of international banking influence is almost equal, but the net connectedness goes from the advanced economies to the Euro area. The emerging economies group appear to be affected the least by the global variables shocks in terms of magnitude, compared to the other groups of economies.

Figure 5.26 sums up the net connectedness direction graph more neatly in a layered ranking graph, which ranks the nodes according to the strength of influence in the whole system, where the strongest node is presented at the top of the layered graph, followed by the second strongest in the next below position, *et cetera*. The width of the edges shows the strength of influence.

The layered graph shows that the US monetary policy is the most influential transmitter of all the global variables and the cross-border banking position of all groups of economies. It net affects every other group in the system but none of them net affects the US monetary policy. The second most important transmitter is the USD value which is net affected by the US monetary policy only, and net positive transmitter to all nodes in the system. The third most important transmitter is global liquidity which is strongly net affected by US monetary policy and weakly net affected by the USD value. This supports the finding in previous section showing that the US monetary policy and USD value are important determinants of the global liquidity.

Among all the group of economies, the most important transmitter in the cross-border banking liquidity is the advanced economy group, followed by the Euro economies, as for the pair of groups the direction of impact goes from the advanced to the Euro groups. This suggests that the global banks located in the advanced economies group and the Euro area is almost equally strong but the impact from banks in the advanced economies to the Euro area seems to be stronger than the other way around. The next most important group is the offshore financial centres' group, which receives the strongest impact from the US monetary policy, and mild net impact from USD value, global liquidity, the cross-border banking liquidity of the advanced and Euro groups. The offshore financial centres' group has a positive net influence on the emerging economies group, making the emerging economies group the least important group in the system. It is probably not really surprising that the global banks located in the offshore financial centres have more influence on global banking condition compared to banks in the emerging economies. Even though the offshore financial centres are merely small jurisdictions, they specialize in providing international banking services which receive significant flows mostly from the advanced economies and Euro area. The emerging economies group receives positive impact from the rest of the groups, while it does not give positive net influence to any of other groups of economies. This shows how prone the monetary condition of the emerging economies are to the external influence from the international banks located in the advanced economies, the Euro area, and even the offshore financial centres.

The same layered ranking connectedness analysis can also be applied to the interconnection between economies. However, as including the whole 36 economies into a web of connection would be cumbersome, we select the biggest economies in terms of their size of cross-border banking position in absolute term in the global economy as presented in graph 5.9. These countries are Germany, Japan, France, Australia, the United Kingdom, USA, and the global variables group. Figures 5.27 represent the *gross* and *net* connectedness of the cross-border banking influence between pair of major economies.

The US monetary policy is again the most important transmitter for the cross-border banking activities globally, with positive net impact to variables in the system. Now that we consider the USA as a single country, it appears that the USA cross-border banking liquidity is the second most important transmitter. It shows that the US monetary policy net influences

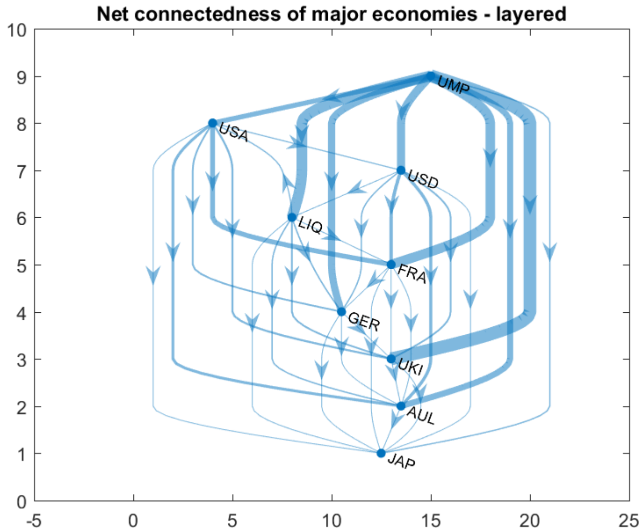


Figure 5.27: Directed graphs representing the connectedness of cross-border banking positions across economies with the highest cross-border banking activities.

the USA cross-border banking activities which then affects the fluctuation of the US Dollar and other major economies. The global liquidity is strongly affected by US monetary policy, weakly net influenced by the US Dollar, but it also affects US cross-border banking activities.

Of all the pair of connections, the influence from the US monetary policy to the international banks' activities in the United Kingdom is the strongest, which does not seem to be surprising as the cross-border banking activities in the United Kingdom is the largest in the world (Figure 5.9). Surprisingly, even though global banks in the UK are the most active in cross-border transactions, they in aggregate are net receivers from most major economies, except Australia and Japan. The international banks located in the USA appears to be the first important transmitter of all country as the banks located in the USA in aggregate have a net positive influence towards the other major economies.

After the USA, the international banks that are located in France is the next important banking condition transmitter, followed by Germany. As shown in Figure 5.10, France and Germany are the important net lender in the global banking system. The United Kingdom and Australia come next as important cross-border banking net transmitters. The United Kingdom hosts international banks with the largest total absolute of cross-border activities in aggregate but without particular net borrowing or lending position, while Australia is the important net borrower in the world. Japan is the least net influencer among the major economies. Although global banks located in Japan is the largest net cross-border lender to the global banking

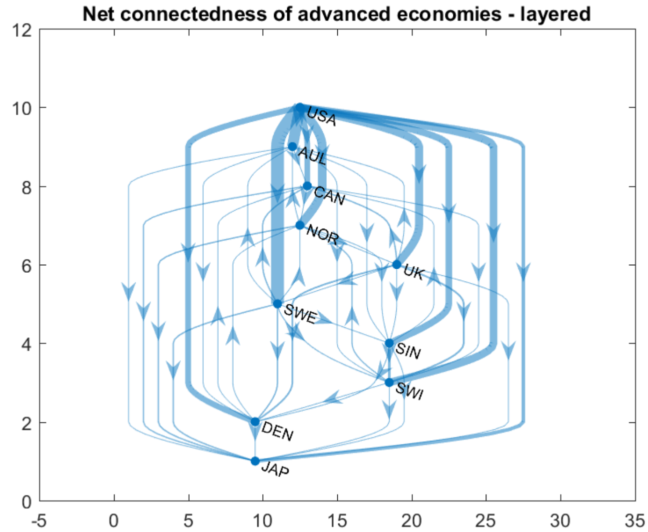


Figure 5.28: Directed graphs representing the connectedness of cross-border banking positions across economies with the highest cross-border banking activities - Advanced economies

system, the activities of the global banks in Japan do not seem to be highly influential to other major economies.

Figure 5.28 depicts the net connectedness layer graphs for the cross-border banking liquidity activities of the countries within the advanced group. The global variables are not included in the picture to focus on the countries. Among the advanced economies, the USA cross-border banking liquidity is again the most influential of all advanced economies, followed by Australia, Canada, Norway, and the United Kingdom. The global banks located in Sweden, Singapore, Switzerland, Denmark, and Japan follow the position.

5.7 Conclusion

We study the interaction between the global liquidity and a set of other global variables that includes US monetary policy, US Dollar value against major trading partners, TED spread, and global credit-to-GDP gaps. We then draw representations of the international banks' connectedness across different economies and groups of economies. Our research objective is to understand how the monetary policy decision of the centre economy and the decision of banks with international establishments give rise to monetary condition spillover across borders.

We find that the US monetary policy rate, US Dollar, global credit-to-GDP gaps, and

TED spread are significant determinants of the global liquidity variable. On impact, positive shocks to the US policy rate and global credit-to-GDP gaps increase global liquidity, while an appreciation of the US Dollar and an increase in the TED spread have the opposite effect. A positive shock to US monetary policy rate appears to significantly increase global aggregate cross-border lending on impact with maximum effect in 1.5 years, but the effect becomes negative in around 2.5 years. Positive monetary policy shock increases TED spread (as a proxy for risk perception) and slows down the global bank leverage (as proxied by the credit-to-GDP gaps) on impact due to the risk-taking channel of monetary policy. Global liquidity dynamics is in line with the global banking leverage cycle, where higher bank leverage ratio is associated with higher global liquidity, and *vice versa*.

Our cross-border banking connectedness network shows that the globally aggregated *within* connectedness measure recede overtime, while the spillover effects tend to grow, suggesting that the international transmission of banking shocks occurs gradually. In net terms, the banking system in almost all countries is affected by the rest of the world, while only the USA is the net transmitter to the global banking system. International banks in several countries influence the global banking system almost by as much as they are influenced, e.g. some advanced countries (France, Germany, Italy, the Netherlands), some offshore financial centres (the Bahamas, Bahrain, Taiwan), and one emerging country (Mexico).

US monetary policy is the most significant net transmitter of cross-border banking position across the globe, followed by the value of the US Dollar, and the aggregate global liquidity variable. The groups of economies ordered by their degree of systemically important financial institutions in the global banking system are the advanced economy group, followed by the Eurozone, the offshore financial centres, and the emerging countries group. This shows that emerging economies group is the most prone to shocks from external monetary conditions. Among the economies with the largest cross-border banking positions, the USA is the globally most influential, followed by France, Germany, the United Kingdom, and Australia. Japan is the least influential among the major economies even though it is the largest net lender globally.

Claims to

Claims from	USA	UK	Germany	France	Italy	Netherlands	Japan	Spain	Cayman Islan	Luxembourg	Ireland	Hong Kong	Canada	Australia	Belgium	Switzerland	Austria	Singapore	Denmark	Brazil
United States		338854	121035	104219	37676	66900	180160	33340	95377	26294	37651	31280	74429	48339	20837	32691	8390	28907	13198	42405
United Kingdom	861394		129614	170074	54349	87582	86775	68148	39423	27322	109103	166791	68871	55089	26816	34407	8419	49324	10140	30306
Germany	522529	518957		178721	151106	131744	71203	136401	55033	123298	94190	14268	27587	24922	42274	57804	89453	20726	30621	8862
France	447761	247975	168337		264646	96560	135448	105581	31267	73216	38676	19011	20133	20451	126298	47512	14294	13436	9660	12812
Italy	34286	48171	206996	39882		19214	5853	35557	2836	23738	8962	1516	2404	2029	6741	11678	84801	1883	2391	1122
Netherlands	257849	171674	153100	82102	58308		24656	62554		16767	21413	8238	23667	39244	0	16152	9034	9547	8270	16358
Japan	832333	158570	110818	94338	33901	52213		20137	185503	70341	25721	60341	40560	53666	17259	16283	5688	45253	6533	14398
Spain	133222	266699	42654	34958	33228	19119	1459		5314	6821	9736	2754	1499	1504	8246	4937	3236	612	2182	66099
Cayman Islands																				
Luxembourg																				
Ireland	44764	165556	33048	14657	23156	8155	6332	16379	22	2930		55	5714	3576	3656	1616	4399	67	2193	17
Hongkong																				
Canada	805713	102602	23746	21460	1351	11766	27906	1567	19038	7869	6671	5329		19921	1517	4570	1244	7954	1362	8254
Australia	58923	113280	7955	7248	578	5574	8759	827	2129	1427	2414	11631	7886		1138	2517	229	16226	534	390
Belgium	66995	85450	37383	56580	35098	86788	2833	20378	6910	17790	37564	3722	2750	3155		5229	4864	2476	3035	457
Switzerland	714340	257279	74156	63034	25066	37654	22761	13637	43351	32964	15226	12314	16017	12965	7387		10805	11428	9747	6786
Austria	13634	17299	36182	8153	13079	8962	406	4106	2603	3822	3788	947	978	1037	2059	6843		1080	1476	299
Singapore																				
Denmark																				
Brazil	18251	7826	1584	1146	394	1947	197	1075	9774	2057	41	65	640	53	362	2049	1132	138	700	
Mexico	3853	339	48	74	8	42	60	212	50	72		0	117	0	8	33	0	0		17
Norway																				
South Korea	20524	3285	2310	883	396	789	7486	216	1106	714	792	8058	2148	2946	373	380	89	4271	97	1358
Finland	2168	3033	2917	2156	615	1457	77	414	713	294	383	115	614	180	606	205	337	370	4023	61
Sweden	62138	41659	63293	7632	1789	7819	1232	3382	6820	5917	2445	679	1628	1352	2939	2900	1330	2347	113618	721
India																				
Portugal																				
Turkey	2560	5089	2764	560	250	2038	88	115	148	319	411	2	22	14	354	338	478	14	109	10
Chinese Taipei	44758	8263	2775	2961	289	2330	8009	157	5149	21749	2506	15660	1122	4712	522	1958	264	5898	130	372
Greece	3399	10332	2747	1631	682	1685	111	240	363	6726	484	157	143	58	745	534	673	42	183	3
Indonesia																				
Chile	3035	317	90	150	21	31	19	48	25	19	15	13	86	7	25	79	4	9	27	731
South Africa																				
Malaysia																				
Panama	3817	263	152	70	4	161	21	16	1067	85	32	13	331	11	64	334	17	8	13	1078
Bermuda																				
Bahamas																				
Cyprus																				
Bahrain																				
Macao SAR																				
	4,958,247	**2,572,773**	**1,223,705**	**892,689**	**735,991**	**650,529**	**591,853**	**524,489**	**514,021**	**472,552**	**418,225**	**362,959**	**299,343**	**295,232**	**270,223**	**251,050**	**249,180**	**222,018**	**220,243**	**212,916**

Claims from	Mexico	Norway	South Korea	Finland	Sweden	India	Portugal	Turkey	Chinese Taipe	Greece	Indonesia	Chile	South Africa	Malaysia	Panama	Bermuda	Bahamas	Cyprus	Bahrain	Macao SAR
United States	62965	10847	45175	5663	14837	28463	2746	10127	20170	6247	7547	8414	6136	10196	2685	7635	6414	797	1747	340
United Kingdom	21319	11716	39984	6928	14195	28459	10151	11752	19865	7442	8139	2868	35031	20608	3323	6193	2053	1509	4532	1386
Germany	5509	27686	11093	15886	31659	11196	20063	11480	3846	21532	5981	3760	5336	3689	3454	5380	3205	4904	1867	167
France	6079	11196	14509	6630	12320	7185	12898	13541	6623	19083	2984	1961	3257	2492	3443	4371	1654	1447	2212	237
Italy	885	2213	295	1242	2201	1159	3098	8457	53	1193	883	152	337	44	611	854	1072	1322	556	7
Netherlands	5153	5089	0	4651	9482	0	4921	0	0	5824	3137	0	997	1402	681	1986	481	736	0	0
Japan	8357	7305	24976	4049	13572	10475	1834	3912	8742	2759	15010	2255	2904	9058	22925	10332	1744	0	1345	0
Spain	87621	3890	367	1812	2139	224	43573	3934	37	911	109	29221	91	29	1407	355	837	45	23	14
Cayman Islands																				
Luxembourg																				
Ireland	15	1144	0	432	2866	6	2658	185	0	3506	1	0	22	7	6	6	5	70	3	0
Hongkong																				
Canada	0	5715	2550	2413	5010	2740	71	1781	2695	0	486	0	181	0	0	1870	7288	0	106	0
Australia	222	915	3971	568	677	3521	102	171	4772	60	2900	177	203	854	52	775	300	37	102	176
Belgium	544	2888	1316	1707	1843	706	3342	2919	633	3659	377	141	217	203	342	458	196	320	696	40
Switzerland	7201	5708	8573	8752	11830	8126	1229	6546	10576	2899	5749	1407	1727	2655	4412	6205	6697	3705	490	221
Austria	365	1024	726	928	1223	371	867	865	46	1707	689	75	360	231	70	152	104	1020	230	12
Singapore																				
Denmark																				
Brazil	232	134	703	40	121	18	1118	64	11	11	38	6957	30	45	280	427	2172	50	35	13
Mexico					15	0	5	0	0	0		4		5	22	0	45	0		
Norway																				
South Korea	1403	129		29	103	3222	177	1002	1348	286	4785	194	357	915	6763	537	0	166	392	117
Finland	46	3157	84		8181	27	80	94	16	117	65	29	16	24	34	40	119	14	12	2
Sweden	417	88651	214	84673		356	214	421	44	268	196	214	67	140	160	2043	225	622	15	6
India																				
Portugal																				
Turkey	40	40	9	10	35	7	9		0	95	0	0	3	3	45	1	12	1140	239	
Chinese Taipei	123	218	3019	73	292	2992	35	185		38	1412	126	573	1218	2025	773	29	85	184	399
Greece	13	121	13	105	58	6	77	19707	0		0	0	226	1	940	125	6	9731	75	0
Indonesia																				
Chile	201	3	56	3	7	63	2	19	4	6			6	3	78	1	11			5
South Africa																				
Malaysia																				
Panama	563	47	21	2	103	6	18	3	9		4	252	4	20		3	195		1	22
Bermuda																				
Bahamas																				
Cyprus																				
Bahrain																				
Macao SAR																				
	209,273	**189,835**	**157,653**	**146,593**	**132,769**	**109,329**	**109,285**	**97,162**	**79,492**	**77,644**	**60,493**	**58,208**	**58,080**	**53,845**	**53,759**	**50,520**	**34,865**	**27,721**	**14,860**	**3,166**

Figure 5.29: Weighting matrix built from the BIS consolidated banking statistics

Chapter 6

Concluding Remarks and Further Research

An ever-increasing process of international financial integration has allowed the intensification of financial spillovers across national borders. The international financial integration also facilitates policy spillovers, where the extent of a policy impact from a centre economy broadens far beyond its national border. Global banks play a significant role in this respect by their ability and willingness to provide global liquidity. This development poses crucial challenges for policymakers in small open economies. In particular, policymakers in these economies need to understand the implications of monetary and policy spillovers on the stability of their jurisdictions. More importantly, they need to be prepared for accurate policy actions to maintain domestic stability in the face of external spillovers. This thesis has attempted to extend our understanding of these developments. By using a combination of empirical and theoretical frameworks, this thesis has studied the consequences of the US QE and its unwinding -as a notable occurrence of large monetary spillovers- on the global economic condition and policymaking. It has analysed the pivotal role of global banks in facilitating the spillovers and influencing the global liquidity dynamics. Finally, this thesis has investigated policy strategy by the emerging economies and discussed their effectiveness.

The second chapter has analysed the macroeconomic and financial implications of the US QE episodes on the US and the global economy and monetary policymaking using the GVAR framework. We find an asymmetric impact of different QE episodes, with QE1 having the most significant impact on the US, the other advanced, and emerging economies macroeconomic variables compared to QE2 and QE3. QE1 appeared to have been successful in halting the recession following the global financial crisis in the global economy. There is evidence of substantial appreciation pressures in non-US countries following QE1 which may suggest the existence of a massive influx of capital flows. However, as the impact of QE1 began to come into effect, inflationary pressures increased notably in the emerging economies. There is evidence that the US QE was trailed by monetary easing across the globe that materialised through either the long or short rates. The results show the effectiveness of QE1 in reducing long-term rates in the US economy as expected. The tendency of lower rates at the longer end of US yield curves and the reduction in global risks seemed to spillovers to other economies. This finding provides some support for the "portfolio-balance channel" that the reduced supply of US long-term securities led investors to seek alternative investments in emerging economies, therefore increasing demand and reducing yields of long-term securities in other economies.

In order to model the US QE formally, the third chapter has utilized an open economy DSGE model to study the implications of a negative foreign interest rate shock and then analysed whether an emerging economy's strategy of the reducing domestic interest rate could neutralise the pressure from the foreign interest rate reduction. Our findings suggest that a foreign monetary policy reduction increases capital inflows into emerging economies, mainly due to higher foreign borrowings by entrepreneurs. Foreign rate reduction decreases the external finance premium, encouraging domestic entrepreneurs to take more risks by borrowing more and then invest more in capital production. This finding supports the international risk-taking channel of monetary policy (Bruno and Shin, 2015a) which maintains that a domestic currency appreciation following a centre country monetary easing makes lending in foreign currency cheaper. Nevertheless, there is a currency appreciation that reduces export product competitiveness. The implications of a responsive domestic monetary policy easing depend on some factors, e.g. the scale of liability dollarization, the size of the capital-intensive sector in the economy, and the primary concern following the foreign negative interest rate shocks. We find that a domestic monetary policy reduction can be successful in slowing down capital inflows, which is desirable if inflows are destabilizing. If capital inflows are the source of funding for capital investment projects however, the effect of domestic monetary easing can be detrimental. Moreover, the effect on the rest of the economy is more detrimental if the relative size of the capital-intensive sector is immense. If inflationary pressures and asset price bubbles following the foreign interest rate reduction are more of a concern, then responsive domestic monetary policy is preferable as it might ease the pressure.

The fourth chapter has examined the impacts of the US Fed interest rate rise (the lift-off) on the emerging economies with capital mobility and flexible exchange rate regime and discussed the effectiveness of a set macroprudential policies as a defence against these impacts. This chapter has extended the DSGE framework used in the third chapter: it is a two-country DSGE model; it establishes global-local bank interactions as the source of global liquidity dynamics; and it enlarges policy options to include macroprudential policy and fixed exchange rates. We find that the cross-border bank lending from the global bank to the local bank (the global liquidity) is the primary channel of cross-border transmission of shocks from the Fed lift-off. A Fed lift-off is expected to be followed by a slowing down in cross-border banking flows to emerging economy, leading to the real exchange rate depreciation, and a reduction in the aggregate credit and investment.

To curb fluctuations in the domestic economy in the aftermath of the shock, we find that monetary policy combined with the macroprudential policy that targets foreign banking capital inflows performs best in most scenarios, suggesting that a policy that focuses on the main channel of cross-border monetary spillovers is preferable. In general, macroprudential policy is effective in minimizing volatilities in credit growth, regardless of the macroprudential instruments. An emerging economy with low financial integration experiences less reduction in the foreign banking flows, but more fluctuations in financial variables such as asset prices, leverage ratio, interest rate spread, and net worth of local banks. Although foreign interest rate shock seems to benefit an emerging economy with low financial integration, in the long run, impediments to capital mobility hold back the economy from reaping the benefits of financial integration like lower steady state cross-border borrowing rate and larger capital inflows in the banking sector. The choice of the exchange rate regime matters for how the emerging economy is affected by the Fed lift-off. In particular, an emerging economy which adopts a fixed exchange rate regime experiences a more significant reduction in the foreign banking flows and greater volatilities in all leading variables. Interestingly, the implementation of macroprudential policies by an emerging economy with a fixed exchange rate regime improves macroeconomic condition as volatilities of leading macroeconomic and financial stability reduces significantly with macroprudential policies.

The fifth chapter has studied the interaction between the global liquidity and a set of global variables that include US monetary policy, US Dollar value against major trading partners, TED spread, and global credit-to-GDP gaps using a VAR framework. We find that the US monetary policy rate, US Dollar, global credit-to-GDP gaps, and TED spread are significant determinants of the global liquidity variable. On impact, positive shocks to the US policy rate and global credit-to-GDP gaps increase global liquidity, while an appreciation of the US Dollar and an increase in the TED spread have the opposite effect. A positive shock to the US monetary policy rate significantly increases the global cross-border lending on impact with maximum effect in 1.5 years, but the effect becomes negative in around 2.5 years. Global liquidity dynamics is in line with the global banking leverage cycle, suggesting that a higher worldwide banks' willingness to extend credit to the real sector is associated with higher cross-border banking supply of funds. Global liquidity dynamics is also strongly determined by USD value, where a USD depreciation causes global liquidity to increase, implying that a cheaper dollar tends to cause international banks to take more risk on overseas markets. The global liquidity is also very sensitive to TED spread, a proxy for credit risk of the counterparty, where a higher TED spread significantly reduces global liquidity with the substantial effect remains until around two years post the shock.

We then used a GVAR framework and a connectedness measure to build a cross-border banking connectedness network. The result reveals that the globally aggregated within connectedness measure recedes overtime, while the spillover effects tend to grow, suggesting that the international transmission of banking shocks occurs gradually. The connectedness network shows that US monetary policy is the most significant net transmitter of cross-border banking positions across the globe, followed by the value of the US Dollar, and the aggregate global liquidity variable. The groups of economies ordered by their degree of systemic importance in the global banking system are the advanced economy group, followed by the Eurozone, the offshore financial centres, and the emerging countries group. This finding shows that emerging economies group is the most prone to shocks from external monetary conditions. Among the economies with the largest cross-border banking positions, the USA is the globally most influential, followed by France, Germany, the United Kingdom, and Australia. Japan is the least influential among the major economies even though it is the most significant net lender globally.

The findings in this thesis give rise to some crucial policy implications. First, this thesis shed some light on the vital role of US monetary policy stance for the global stability via the global banks' connectedness network. In particular, US policy stance significantly affects global banks' willingness and ability to extend cross-border liquidity. The fluctuations of the global liquidity influence domestic credit condition, and thus, the monetary and financial stability in the rest of the world. This finding should advise policymakers in the core economies on the increasing global dimensions of their tasks. In particular, the implications of their policy stance is increasingly linked to the monetary condition, and thus policymaking in the rest of the world. Hence, this awareness should encourage core economies' policymakers such as the Federal Reserve -and may also apply to the European Central Bank and the Bank of England- to internalise the possible international implications of their policy stances in every decision making.

In addition to the US policy stance, the global banks also play a pivotal role in the global liquidity dynamics. The global banks' willingness and ability to extend foreign lending facilitate cross-border liquidity spillovers via the international banking network, which determines the global liquidity fluctuations. This result should advise relevant international authorities such as the Bank for International Settlements and the International Monetary Fund to strengthen the international cooperation for banking supervision and encourage policy coordination among national authorities on the cross-border banking supervision.

Also, the ranking of countries (or groups of countries) in the importance of the global banking network provides policy-relevant information about the handling of possible banking crisis spillovers in the future. In particular, international authorities should give more supervision focus on the most influential countries (or groups of countries) in the banking network, as a banking crisis in a particular country tends to have a more severe implication globally the higher the position it is in the network. Hence, a banking crisis in the advanced or the Euro countries can have major international ramifications, while a banking crisis in emerging economies is more likely to be localised. As another example, although the United Kingdom is neither a significant net lender nor a significant net borrower globally, its banking activities is more prominent than Japan which is the most dominant net lender globally.

This thesis also reveals essential policy implications for the emerging economies. First, monetary policy in most emerging economies may not be as independent as suggested by the standard macroeconomic theory, even after the implementation of a flexible exchange rate regime. In particular, the extent to which domestic independence can be achieved by an emerging economy varies across time depending on the magnitude of the external spillovers. When the external spillovers, either from financial condition or policy-based, are massive, the independence of domestic monetary policy in the emerging economies is profoundly jeopardized. The global financial crisis and QE1 were two examples of times when external spillovers are significant for emerging economies. During a massive external spillover, domestic monetary policy transmission may not be as powerful in achieving its policy target such as driving market interest rates, managing domestic credit activities, and maintaining domestic stability in general. To recognise periods of massive external spillovers through global liquidity, emerging economies' policymakers should keep track on the movement of the US monetary policy, USD value, TED spread, and the global credit-to-GDP gaps as important origins for the global liquidity dynamics. During the period of massive external spillovers, emerging economies need to supplement monetary policy with additional measures such as macroprudential policy and capital flows management, thus providing more leeway for monetary policy manoeuvre.

The findings in this thesis provide support for the currently growing research area in the optimal policymaking which takes into account cross-border spillovers. In particular, as the impact of policymaking in particular countries might be observed far beyond their national borders, there is a scope for the first-best solution of policy coordination across economies. Although monetary policy coordination across countries seems politically infeasible, at least a second-best solution which is an internalisation of each others' policy stance is worth considering (Eichengreen, 2013; Taylor, 2013). Possible future research in this regard could be directed towards policy coordination to improve macroeconomic management in affected economies as the external spillover impact can be consequential. Similarly, as global banking activities facilitate significant liquidity spillovers, future research can be extended in the ways the cross-border banking supervisions be improved to increase global financial stability.

Another clear avenue for future research in this area is regarding the modelling framework. In the fourth chapter, we have examined the spillover effects through the cross-border banking borrowing and lending in the face of centre country's policy shock. Empirical regularity shows that there is a significant effect for unexpected policy announcement, even before the actual policy is implemented. Hence, future research avenue will be to add the model's framework with an additional channel of contagion from policy announcement that shifts market perception towards future policy rates and financial conditions. In this chapter, we also have analysed the effectiveness of macroprudential instruments. A promising future research is to embed the model framework with asymmetries in macroprudential policy effectiveness. In particular, it would be interesting to explore how the results change when we allow the effectiveness of the macroprudential policy to be different in times of boom and bust; in the intensity of market failures; or in the phases of the financial cycle.

In the fifth chapter, we have established the global banking connectedness network. The future research opportunities for the banking connectedness network is to analyse the network in different periods of time. For instance, one can divide the data into two subsets of data by its period: the normal period and the crisis period. The GVAR estimation and the connectedness measurement can then be applied to the two subsets of data. It would be interesting to see whether the connectedness network will change if the dataset is divided into a period in around the crisis and normal times. The same chapter discusses the role of offshore financial centres in the global banking network only briefly. Although most of the offshore financial centres are small countries with very small population, their role in the global banking network is crucial, far more crucial than emerging economies with notably more population. Hence, a fruitful future research could be directed towards examining the role of offshore financial centres on the global liquidity dynamics, the countries that are important for offshore financial centres, and the international supervision towards the centres.

Appendix A

Appendices to Chapter 2

A.1 Global Vector Auto Regression/Global Vector Error Correction Model

For each economy, there is a VAR model containing a set of equations that relates the vector $\mathbf{x}_{it}$ of k_i domestic variables to the global economy via foreign variables $\mathbf{x}^*_{it}$ plus deterministic variables such as time trends and global exogenous variables (here, world financial oil and VIX index). We consider the VARX*(p_i, q_i) structure:

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Phi}_{i1}\mathbf{x}_{i,t-1} + \cdots + \mathbf{\Phi}_{ip_i}\mathbf{x}_{i,t-p_i} + \mathbf{\Lambda}_{i0}\mathbf{x}^*_{it} + \mathbf{\Lambda}_{i1}\mathbf{x}^*_{i,t-1} + \cdots + \mathbf{\Lambda}_{iq_i}x^*_{i,t-q_i} + \mathbf{u}_{it}, \quad (A.1)$$

$t = 1, 2, ..., T; i = 0, 1, 2, ..., N$

where $\mathbf{\Phi}_{ip_i}$ is a $k_i \times k_i$ matrix of lagged coefficients, $\mathbf{\Lambda}_{iq_i}$ are $k_i \times k^*_i$ matrix of coefficients associated with the foreign-specific variables, and $\mathbf{u}_{it}$ is a $k_i \times 1$ vector of idiosyncratic country-specific shocks.

The ECM form of the VARX*$(2, 2)$ specification can be written as VECMX*$(1, 1)$ model

$$\Delta\mathbf{x}_{it} = \mathbf{c}_{i0} - \boldsymbol{\alpha}_i\boldsymbol{\beta}'_i[\mathbf{z}_{i,t-1} - \boldsymbol{\gamma}_i(t-1)] + \mathbf{\Lambda}_{i0}\Delta\mathbf{x}^*_{it} + \mathbf{\Gamma}_i\Delta\mathbf{z}_{i,t-1} + \mathbf{u}_{i,t} \quad (A.2)$$

where $\mathbf{z}_(i,t) = (\mathbf{x}'_{it}, \mathbf{x}^{*'}_{it})'$, $\boldsymbol{\alpha}_i$ is a $k_i \times r_i$ matrix of rank r_i and $\boldsymbol{\beta}_i$ is a $(k_i + k*_i) \times r_i$ matrix of rank r_i.

The VECMX is estimated using reduced regression techniques. In this case, $\mathbf{x}_i^*t$ are treated as 'long-run forcing' or I(1) weakly exogenous with respect to the parameters of the VARX* model. The VARX* model is estimated for each country separately conditional on $\mathbf{x}_i^*t$. Then we can recover the number of cointegrating relations r_i, the speed of adjustment coefficients $\boldsymbol{\alpha}_i$ and the cointegrating vectors $\boldsymbol{\beta}_i'$ for each country model. The rest of parameters of the conditional model are then estimated by OLS regressions [1]

$$\Delta\mathbf{x}_{it} = \mathbf{c}_{i0} - \boldsymbol{\delta}_i ECM_{i,t-1} + \Lambda_{i0}\Delta\mathbf{x}_{it}^* + \boldsymbol{\Gamma}_i\Delta\mathbf{z}_{i,t-1} + \mathbf{u}_{it} \tag{A.3}$$

where $ECM_{i,t-1}$ are the error correction terms corresponding to the r_i cointegrating relations of the i^{th} country model. The corresponding cointegrating VARX* models are estimated and the rank of their cointegrating space is determined using the error-correction form of the individual country models given by equation A.1 and computed using Johansen's trace and maximal eigenvalue statistics as set out in Pesaran et al. (2000).

Although estimation is done on a country by country basis, the GVAR model is solved for the world as a whole, i.e. in terms of a $k \times 1$ global variable vector, $k = \sum_{i=0}^{N} k_i$, taking account of the fact that all the variables are endogenous to the system as a whole. In particular, after estimating the VECMX* model as in model A.3, we recover the VARX* (p_i, q_i) models for each country

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \boldsymbol{\Phi}_{i1}\mathbf{x}_{i,t-1} + \cdots + \boldsymbol{\Phi}_{ip_i}\mathbf{x}_{i,t-p_i} + \boldsymbol{\Lambda}_{i0}\mathbf{x}_{it}^* + \boldsymbol{\Lambda}_{i1}\mathbf{x}_{i,t-1}^* + \cdots + \boldsymbol{\Lambda}_{iq_i}x_{i,t-q_i}^* + \mathbf{u}_{it}, \tag{A.4}$$

From the country-specific models, we define the $(k_i + k_i^*) \times 1$ vector

$$\mathbf{z}_{it} = \begin{pmatrix} \mathbf{x}_{it} \\ \mathbf{x}_{it}^* \end{pmatrix}$$

and rewrite model A.4 as

$$\mathbf{A}_{i0}\mathbf{z}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{A}_{i1}\mathbf{z}_{it-1} + \cdots + \mathbf{A}_{ip_i}\mathbf{z}_{it-p_i} + \mathbf{u}_{it}, \tag{A.5}$$

where

$$\mathbf{A}_{i0} = (\mathbf{I}_{ki}, -\boldsymbol{\Lambda}_{i0}), \qquad \mathbf{A}_{ij} = (\boldsymbol{\Phi}_{ij}, \boldsymbol{\Lambda}_{ij}) \tag{A.6}$$

[1] We use the procedures provided in the GVAR Toolbox provided by Vanessa Smith and Alessandro Galesi. The GVAR toolbox can be downloaded from https://sites.google.com/site/gvarmodelling/gvar-toolbox

for $j = 1, \ldots, p_i$.

The dimensions of $\mathbf{A}_{i0}$ and $\mathbf{A}_{ij}$ are $(k_i + k_i^*) \times 1$, and $\mathbf{A}_{i0}$ has a full row rank, that is $\text{Rank}(\mathbf{A}_{i0}) = k_i$. Collecting all the country-specific variables together in the $k \times 1$ global vector $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, \ldots, \mathbf{x}'_{Nt})'$ where $k = \sum_{i=0}^{N} k_i$ is the total number of the endogenous variables in the global model, it can be seen that the country specific variables can all be written in terms of $\mathbf{x}_t$:

$$\mathbf{z}_i t = \mathbf{W}_i \mathbf{x}_t, \qquad i = 0, 1, 2, \ldots, N \tag{A.7}$$

where $\mathbf{W}_i$ is a $(k_i + k_i^*) \times k$ matrix of fixed (known) constants defined in terms of the country specific weights. Thus, $\mathbf{W}_i$ can be viewed as the 'link' matrix that allows the country-specific models to be written in terms of the global variable vector, $\mathbf{x}_t$.

Using that in model A.5 we have:

$$\mathbf{A}_{i0} \mathbf{W}_i \mathbf{x}_t = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \mathbf{A}_{i1} \mathbf{W}_i \mathbf{x}_{t-1} + \cdots + \mathbf{A}_{ip_i} \mathbf{W}_i \mathbf{x}_{t-p_i} + \mathbf{u}_{it}, \tag{A.8}$$

Stacking equation A.8 for all countries yields:

$$\mathbf{G}_0 \mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1 t + \mathbf{G}_1 \mathbf{x}_{t-1} + \cdots + \mathbf{G}_p \mathbf{x}_{t-p} + \mathbf{u}_t, \tag{A.9}$$

where

$$\mathbf{a}_0 = \begin{pmatrix} \mathbf{a}_{00} \\ \mathbf{a}_{10} \\ \vdots \\ \mathbf{a}_{N0} \end{pmatrix}, \mathbf{a}_1 = \begin{pmatrix} \mathbf{a}_{01} \\ \mathbf{a}_{11} \\ \vdots \\ \mathbf{a}_{N1} \end{pmatrix}, \mathbf{u}_t = \begin{pmatrix} \mathbf{u}_{0t} \\ \mathbf{u}_{1t} \\ \vdots \\ \mathbf{u}_{Nt} \end{pmatrix} \tag{A.10}$$

$$\mathbf{G}_0 = \begin{pmatrix} \mathbf{A}_{00} \mathbf{W}_0 \\ \mathbf{A}_{10} \mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N0} \mathbf{W}_N \end{pmatrix}, \mathbf{G}_j = \begin{pmatrix} \mathbf{A}_{0j} \mathbf{W}_0 \\ \mathbf{A}_{1j} \mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{Nj} \mathbf{W}_N \end{pmatrix} \tag{A.11}$$

for $j = 1, 2, \ldots, p$,

$\mathbf{G}_0$ is a known and in general will be non-singular, therefore we can pre-multiply A.9 by $\mathbf{G}_0^{-1}$.

$$\mathbf{x}_t = \mathbf{G}_0^{-1}\mathbf{a}_0 + \mathbf{G}_0^{-1}\mathbf{a}_1 t + \mathbf{G}_0^{-1}\mathbf{G}_1\mathbf{x}_{t-1} + \cdots + \mathbf{G}_0^{-1}\mathbf{G}_p\mathbf{x}_{t-p} + \mathbf{G}_0^{-1}\mathbf{u}_t, \tag{A.12}$$

to obtain the GVAR(p) model

$$\mathbf{x}_t = \mathbf{b}_0 + \mathbf{b}_1 t + \mathbf{F}_1\mathbf{x}_{t-1} + \cdots + \mathbf{F}_p\mathbf{x}_{t-p} + \boldsymbol{\varepsilon}_t, \tag{A.13}$$

where

$$\mathbf{b}_0 = \mathbf{G}_0^{-1}\mathbf{a}_0,\ \mathbf{b}_1 = \mathbf{G}_0^{-1}\mathbf{a}_1$$

$$\mathbf{F}_j = \mathbf{G}_0^{-1}\mathbf{G}^j,\ j = 1, 2, \ldots, p,\ \boldsymbol{\varepsilon}_t = \mathbf{G}_0^{-1}\mathbf{u}_t.$$

Equation A.13 can be solved recursively and used for further analysis like forecasting or impulse response analysis.

A.2 Principal Component Analysis

The principal component analysis is a statistical procedure to reduce data dimension of a set of observable and possibly related variables into some variables of a lesser dimension that capture most variations of the original variables. Each principal component is a linear combination of the original variables. The principal components are obtained from eigendecomposition of the dataset's covariance matrix such that the first principal component captures the largest variance of original datasets, the second principal component has the second largest variance, and so on. In addition, the decomposition is such that each principal component is orthogonal to each other so that no redundancy of data would occur between different series of principal components.

We consider an $n-$dimensional stochastic vector $\mathbf{x} = (x_1 \dots x_n)'$ such that $E[\mathbf{x}] = 0$, and we define $\mathbf{\Gamma_x} = E[\mathbf{xx'}]$. The covariance matrix $\mathbf{\Gamma_x}$ is a symmetric and positive definite matrix and can always be factorized as

$$\mathbf{\Gamma_x} = \mathbf{PDP'} \tag{A.14}$$

where $\mathbf{P}$ in an $n \times n$ orthogonal matrix of eigenvectors, i.e. $\mathbf{PP'} = \mathbf{P'P} = \mathbf{I}$ and $\mathbf{P} = (\mathbf{p}_1 \dots \mathbf{p}_n)$, and $\mathbf{D} = diag(\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_n > 0)$ contains the ordered eigenvalues.

Then,

$$\mathbf{\Gamma_x p}_j = \lambda_j \mathbf{p}_j \tag{A.15}$$

and

$$\mathbf{\Gamma_x} = \sum_{j=1}^{n} \lambda_j \mathbf{p}_j \mathbf{p}_j'. \tag{A.16}$$

To obtain the eigenvalues, it is essential to recall that the eigenvalues solve

$$det(\mathbf{\Gamma_x} - \lambda_j \mathbf{I}_n) = 0, \tag{A.17}$$

then once we have the eigenvalues, the eigenvectors can be found by solving

$$(\mathbf{\Gamma}_{\mathbf{x}} - \lambda_j \mathbf{I}_n)\mathbf{p}_j = 0. \tag{A.18}$$

The linear combination $\mathbf{p}_j'\mathbf{x}$ is called the j-th principal component of $\mathbf{x}$.

A.3 Conditional Forecasts

Conditional forecasts are basically forecasts of the global model which are obtained subject to a set of restrictions, written more generally as

$$\mathbf{\Psi x}_{T+j} = \mathbf{d}_{T+j}, \quad j = 1, 2, \ldots, \bar{H}, \tag{A.19}$$

where $\mathbf{\Psi}$ is an $m \times k$ matrix, m is the number of variables to be restricted, and $\mathbf{d}_{T+j}$ is a $m \times 1$ vector of known constants. For example we have $m = 2$ with $k_0 = 6$ (the number of endogenous variables in the US model). The matrix $\mathbf{\Psi}$ is then defined as

$$\mathbf{\Psi} = \begin{pmatrix} \mathbf{0}_{1\times(k-k_0)} & 0 & 0 & 0 & 1 & 0 & 0 \\ \mathbf{0}_{1\times(k-k_0)} & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \tag{A.20}$$

and $\mathbf{d}_{T+j} = (r^S_{0,T+j}, r^L_{0,T+j})', j = 1, 2, \ldots, \bar{H}$ contains the predefined values for the US short and long run interest rates for each future quarter j.

Point forecasts of X_{T+h} under the restrictions are given by

$$\mu^*_h = E(\mathbf{x}_{T+h} \| \mathcal{I}_T, \mathbf{\Psi} X_{T+j} = \mathbf{d}_{T+j}), \quad j = 1, 2, \ldots, \bar{H}. \tag{A.21}$$

It is assumed that the restriction do not affect the GVAR parameters, $F_i = 1, 2$ and the covariance matrix, $\mathbf{\Sigma}_\varepsilon$, associated with the residuals, ε_t, of the GVAR model.

First we consider that the ex-ante forecasts are normally distributed so that

$$\mathbf{x}_{T+h} \parallel \mathcal{I}_T \sim N(\boldsymbol{\mu}_h, \mathbf{\Omega}_{hh}), \tag{A.22}$$

where Ω_{hh} is given by

$$\mathbf{\Omega}_{hh} = S \sum_{l=0}^{h-1} \mathbf{F}^l \mathbf{\Sigma} \mathbf{F}'^l S^l, \tag{A.23}$$

with

$$\mathbf{\Sigma} = \begin{pmatrix} \mathbf{\Sigma}_\varepsilon & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{pmatrix} \tag{A.24}$$

and $\mathbf{\Sigma}_\varepsilon = Cov(\varepsilon_{T+h-i})$

We have

$$\mathbf{x}_{T+h} = \boldsymbol{\mu}_h + \boldsymbol{\xi}_{T+h} \tag{A.25}$$

where

$$\boldsymbol{\xi}_{T+h} = \sum_{l=0}^{h-1} S\mathbf{F}^l \mathbf{E}_{T+h-1} \tag{A.26}$$

The restrictions now imply that

$$\boldsymbol{\Psi}\boldsymbol{\xi}_{T+j} = \mathbf{d}_{T+j} - \boldsymbol{\Psi}\boldsymbol{\mu}_j \tag{A.27}$$

Setting $\mathbf{g}_j = \mathbf{d}_{T+j} - \boldsymbol{\Psi}\boldsymbol{\mu}_j$, equation A.27 can be written as

$$(\mathbf{I}_{\bar{H}} \otimes \boldsymbol{\Psi})\boldsymbol{\xi}_{\bar{H}} = \mathbf{g}_{\bar{H}}, \tag{A.28}$$

where $\boldsymbol{\xi}_{\bar{H}} = (\boldsymbol{\xi}'_{T+1}, \boldsymbol{\xi}'_{T+2}, \ldots, \boldsymbol{\xi}'_{T+\bar{H}})'$ and $\mathbf{g}_{\bar{H}} = (\mathbf{g}'_1, \mathbf{g}'_2, \ldots, \mathbf{g}'_{\bar{H}})'$.

Under joint normality of the shocks, we have

$$\begin{aligned} E(\boldsymbol{\xi}_{T+h} \,\|\, \mathcal{I}_T, \quad \boldsymbol{\Psi}\mathbf{x}_{T+j} = \mathbf{d}_{T+j}, \quad j = 1, 2, \ldots, \bar{H}) \\ = E(\boldsymbol{\xi}_{T+h} \,\|\, \mathcal{I}_T, \quad (\mathbf{I}_{\bar{H}} \otimes \boldsymbol{\Psi})\boldsymbol{\xi}_{\bar{H}} = \mathbf{g}_{\bar{H}}) \\ = (\zeta'_{h\bar{H}} \otimes \mathbf{I}_k)\boldsymbol{\Omega}_{\bar{H}}(\mathbf{I}_{\bar{H}} \otimes \Psi')[(\mathbf{I}_{\bar{H}} \otimes \Psi)\boldsymbol{\Omega}_{\bar{H}}(\mathbf{I}_{\bar{H}} \otimes \Psi')]^{-1}\mathbf{g}_{\bar{H}} \end{aligned} \tag{A.29}$$

where $\zeta'_{h\bar{H}}$ is a $\bar{H} \times 1$ selection vector with unity as its h^{th} element and zeros elsewhere, and $\boldsymbol{\Omega}_{\bar{H}}$ is the $k\bar{H} \times k\bar{H}$ matrix

$$\boldsymbol{\Omega}_{\bar{H}} = \begin{pmatrix} \boldsymbol{\Omega}_{11} & \boldsymbol{\Omega}_{12} & \cdots & \boldsymbol{\Omega}_{1\bar{H}} \\ \boldsymbol{\Omega}_{21} & \boldsymbol{\Omega}_{22} & \cdots & \boldsymbol{\Omega}_{2\bar{H}} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{\Omega}_{\bar{H}1} & \boldsymbol{\Omega}_{\bar{H}2} & \cdots & \boldsymbol{\Omega}_{1\bar{H}\bar{H}} \end{pmatrix} \tag{A.30}$$

The diagonal elements of $\boldsymbol{\Omega}_{\bar{H}}$, that is $\{\boldsymbol{\Omega}_{ii}\}_{i=1}^{\bar{H}}$, are given by equation A.23, while off-diagonal elements can be expressed as

$$\boldsymbol{\Omega}_{ij} = \begin{cases} S(\sum_{l=0}^{i-1} \mathbf{F}^l \boldsymbol{\Sigma} \mathbf{F}'^l)\mathbf{F}'^{(j-i)} S', & i < j \\ S\mathbf{F}'^{(i-j)}(\sum_{l=0}^{j-1} \mathbf{F}^l \boldsymbol{\Sigma} \mathbf{F}'^l) S', & i > j \end{cases} \tag{A.31}$$

where $\boldsymbol{\Sigma}$ is defined by A.24.

Hence, the conditional point forecasts are given by

$$\boldsymbol{\mu}^*_h = \boldsymbol{\mu}_h + (\zeta'_{h\bar{H}} \otimes \mathbf{I}_k)\boldsymbol{\Omega}_{\bar{H}}(\mathbf{I}_{\bar{H}} \otimes \Psi')[(\mathbf{I}_{\bar{H}} \otimes \Psi)\boldsymbol{\Omega}_{\bar{H}}(\mathbf{I}_{\bar{H}} \otimes \Psi')]^{-1}\mathbf{g}_{\bar{H}} \tag{A.32}$$

Appendix B

Appendices to Chapter 3

B.1 Steady State Relationships

$$i = \frac{1-\beta}{\beta} \tag{B.1}$$

$$i^* = i \tag{B.2}$$

$$S = 1 \tag{B.3}$$

$$R_K N = 1 \tag{B.4}$$

$$R_K X = 1 \tag{B.5}$$

$$H_X^e = 1 \tag{B.6}$$

$$H_N^e = 1 \tag{B.7}$$

$$P = 1 \tag{B.8}$$

$$P_N = 1 \tag{B.9}$$

$$P_M = 1 \tag{B.10}$$

$$P_M^* = 1 \tag{B.11}$$

$$P_X^* = 1 \tag{B.12}$$

$$Y_N = 0.7 \tag{B.13}$$

$$Y_M = 0.3 \tag{B.14}$$

$$H_N = 1 \tag{B.15}$$

$$D = 1 \tag{B.16}$$

B.2 Steady State Equations

$$Q_N = P \tag{B.17}$$

$$Q_X = P \tag{B.18}$$

$$MC_N = P_N \left(\frac{\lambda - 1}{\lambda} \right) \tag{B.19}$$

$$P_X = SP_X^* \tag{B.20}$$

$$R_N = Q_N(R_{KN} - 1 + \delta) \tag{B.21}$$

$$R_X = Q_X(R_{KX} - 1 + \delta) \tag{B.22}$$

$$Y_X = \frac{P_M Y_M}{P_X} \tag{B.23}$$

$$K_N = \frac{\alpha MC_N Y_N}{R_N} \tag{B.24}$$

$$K_X = \frac{\gamma MC_X Y_X}{R_X} \tag{B.25}$$

$$I_X = \delta K_X \tag{B.26}$$

$$I_N = \delta K_N \tag{B.27}$$

$$W_N^e = \frac{MC_N(1-\alpha)(1-\omega)Y_N}{H_N^e} \tag{B.28}$$

$$W_X^e = \frac{P_X(1-\gamma)(1-\omega)Y_X}{H_X^e} \tag{B.29}$$

$$W = \frac{MC_N(1-\alpha)\omega Y_N}{H_N} \tag{B.30}$$

$$H_X = \frac{P_X(1-\gamma)\omega Y_X}{W} \tag{B.31}$$

$$H = H_X + H_N \tag{B.32}$$

$$C = \left(\frac{W}{\eta H^{\psi} P} \right)^{\frac{1}{\sigma}} \tag{B.33}$$

$$C_N = a \left(\frac{P_N}{P} \right)^{-\rho} C \tag{B.34}$$

$$C_M = (1-a) \left(\frac{P_M}{P} \right)^{-\rho} C \tag{B.35}$$

$$Z_N = \frac{\nu(R_{KN}Q_N K_N - (1+i^*)Q_N K_N)}{1 - \nu(1+i^*)} \tag{B.36}$$

$$Z_X = \frac{\nu(R_{KX}Q_X K_X - (1+i^*)Q_X K_X)}{1 - \nu(1+i^*)} \tag{B.37}$$

$$premium_N = \frac{R_{KN}}{(1+i_{t+1}^*)\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}} \tag{B.38}$$

$$premium_X = \frac{R_{KX}}{(1+i^*_{t+1})\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}} \tag{B.39}$$

$$C^e_N = Z_N \frac{1-\nu}{\nu} \tag{B.40}$$

$$C^e_X = Z_X \frac{1-\nu}{\nu} \tag{B.41}$$

$$D^e_N = \frac{1}{PZ_NS}\left(\frac{R_{KN}}{1+i^*}\right)^{\frac{1}{\omega_N}} - 1 \tag{B.42}$$

$$D^e_X = \frac{1}{PZ_XS}\left(\frac{R_{KX}}{1+i^*}\right)^{\frac{1}{\omega_N}} - 1 \tag{B.43}$$

$$D^e = D^e_N + D^e_X \tag{B.44}$$

B.3 Log-Linearized Equations

$$\widetilde{W_t} = \psi\widetilde{H}_t + \widetilde{P}_t + \sigma\widetilde{C}_t \tag{B.45}$$

$$\widetilde{i_{t+1}} = -\frac{1+i}{i}(\sigma\widetilde{C_t} + \widetilde{P}_t - \sigma\widetilde{C_{t+1}} - \widetilde{P_{t+1}}) \tag{B.46}$$

$$\widetilde{i}_t = \widetilde{i}^*_t + \widetilde{S}_t - \widetilde{S_{t-1}} \tag{B.47}$$

$$\widetilde{C_{Nt}} = -\rho\widetilde{P_{Nt}} + \rho\widetilde{P}_t + \widetilde{C}_t \tag{B.48}$$

$$\widetilde{C_{Mt}} = -\rho\widetilde{P_{Mt}} + \rho\widetilde{P}_t + \widetilde{C}_t \tag{B.49}$$

$$\widetilde{P}_t = a\left(\frac{P_N}{P}\right)^{1-\rho}\widetilde{P_{Nt}} + (1-a)\left(\frac{P_M}{P}\right)^{1-\rho}\widetilde{P_{Mt}} \tag{B.50}$$

$$\widetilde{W}_t = \widetilde{MCN}_t + \widetilde{Y_{Nt}} - \widetilde{H_{Nt}} \tag{B.51}$$

$$\widetilde{W}_t = \widetilde{P_{Xt}} + \widetilde{Y_{Xt}} - \widetilde{H_{Xt}} \tag{B.52}$$

$$\widetilde{R_{Nt}} = \widetilde{MCN_t} + \widetilde{Y_{Nt}} - \widetilde{K_{Nt-1}} \tag{B.53}$$

$$\widetilde{R_{Xt}} = \widetilde{P_{Xt}} + \widetilde{Y_{Xt}} - \widetilde{K_{Xt-1}} \tag{B.54}$$

$$\widetilde{Y_{Nt}} = AN_t + \alpha\widetilde{K_{Nt-1}} + \Omega(1-\alpha)\widetilde{H_{Nt}} \tag{B.55}$$

$$\widetilde{Y_{Xt}} = AX_t + \gamma\widetilde{K_{Xt-1}} + \Omega(1-\gamma)\widetilde{H_{Xt}} \tag{B.56}$$

$$\widetilde{P_{Nt}} = \frac{\lambda}{\lambda-1}P_N\widetilde{MCN_t} \tag{B.57}$$

$$\widetilde{P_{Mt}} = \frac{\lambda}{\lambda-1}P_M^*S(\widetilde{P_{Mt}^*} + \widetilde{S}_t) \tag{B.58}$$

$$\widetilde{P_{Xt}} = \widetilde{S}_t + \widetilde{P_X^*} \tag{B.59}$$

$$\widetilde{Q_{Xt}} = \widetilde{P}_t - \left(\frac{Q_X\psi_I I_X}{PK_X}\right)\widetilde{K_{Xt-1}} + \left(\frac{Q_X\psi_I I_X}{PK_X}\right)\widetilde{I_{Xt}} \tag{B.60}$$

$$\widetilde{Q_{Nt}} = \widetilde{P}_t - \left(\frac{Q_N\psi_I I_N}{PK_N}\right)\widetilde{K_{Nt-1}} + \left(\frac{Q_N\psi_I I_N}{PK_N}\right)\widetilde{I_{Nt}} \tag{B.61}$$

$$\widetilde{K_{Xt}} = \frac{I_X}{K_X}\widetilde{I_{Xt}} + (1-\delta)\widetilde{K_{Xt-1}} \tag{B.62}$$

$$\widetilde{K_{Nt}} = \frac{I_N}{K_N}\widetilde{I_{Nt}} + (1-\delta)\widetilde{K_{Nt-1}} \tag{B.63}$$

$$\widetilde{R_{KNt}} = \left(\frac{\omega_N Z_N}{K_N Q_N}\right)(K_N\widetilde{K_{Nt}} + Q_N\widetilde{Q_{Nt-1}} - Z_N\widetilde{Z_{Nt}} + \widetilde{i^*} + \widetilde{S}_t - \widetilde{S_{t-1}}) \tag{B.64}$$

$$\widetilde{R_{KXt}} = \left(\frac{\omega_X Z_X}{K_X Q_X}\right)(K_X\widetilde{K_{Xt}} + Q_X\widetilde{Q_{Xt-1}} - Z_X\widetilde{Z_{Xt}} + \widetilde{i^*} + \widetilde{S}_t - \widetilde{S_{t-1}}) \tag{B.65}$$

$$\widetilde{R_{KNt}} = \frac{R_N}{R_{KN}Q_N}\widetilde{R_{Nt}} + \frac{1-\delta}{R_{KN}}\widetilde{Q_{Nt}} + \frac{2\psi_I Q_N I_N^2}{K_N^2}(\widetilde{I_{Nt}} - \widetilde{K_{Nt-1}}) - \widetilde{Q_{Nt-1}} \tag{B.66}$$

$$\widetilde{R_{KXt}} = \frac{R_X}{R_{KX}Q_X}\widetilde{R_{Xt}} + \frac{1-\delta}{R_{KX}}\widetilde{Q_{Xt}} + \frac{2\psi_I Q_X I_X^2}{K_X^2}(\widetilde{I_{Xt}} - \widetilde{K_{Xt-1}}) - \widetilde{Q_{Xt-1}} \tag{B.67}$$

$$\begin{aligned}\widetilde{Z_{Nt}} = \frac{\nu}{Z_N}(&R_{KN}Q_N K_N \widetilde{R_{KNt-1}} + (Q_N K_N(1+i^* + R_{KN}))(\widetilde{Q_{Nt-1}} + \widetilde{K_{Nt-1}}) + \\ &(1+i^*)Z_N\widetilde{Z_{Nt-1}} - (1+i^*)(Q_N K_N - Z_N)S(\widetilde{S}_t - \widetilde{S_{t-1}}) - (Q_N K_N - Z_N)i^*\widetilde{i_t^*})\end{aligned} \tag{B.68}$$

$$\begin{aligned}\widetilde{Z_{Xt}} = \frac{\nu}{Z_X}(&R_{KX}Q_X K_X \widetilde{R_{KXt-1}} + (Q_X K_X(1+i^* + R_{KX}))(\widetilde{Q_{Xt-1}} + \widetilde{K_{Xt-1}}) + \\ &(1+i^*)Z_X\widetilde{Z_{Xt-1}} - (1+i^*)(Q_X K_X - Z_X)S(\widetilde{S}_t - \widetilde{S_{t-1}}) - (Q_X K_X - Z_X)i^*\widetilde{i_t^*})\end{aligned} \tag{B.69}$$

$$\widetilde{C^e_{Nt+1}} = \frac{1-\nu}{\nu}\widetilde{Z_{Nt+1}} \tag{B.70}$$

$$\widetilde{C^e_{Xt+1}} = \frac{1-\nu}{\nu}\widetilde{Z_{Xt+1}} \tag{B.71}$$

$$\widetilde{D^e_{Nt}} = -\widetilde{S_{t-1}} + (SD^e_N)(Q_N K_N(\widetilde{Q_{Nt-1}} + \widetilde{K_{Nt}})) - Z_N\widetilde{Z_{Nt}} \tag{B.72}$$

$$\widetilde{D^e_{Xt}} = -\widetilde{S_{t-1}} + (SD^e_X)(Q_X K_X(\widetilde{Q_{Xt-1}} + \widetilde{K_{Xt}})) - Z_X\widetilde{Z_{Xt}} \tag{B.73}$$

$$\widetilde{D^e} = \left(\frac{D^e_N}{D^e}\right)\widetilde{D_N t^e} + \left(\frac{D^e_X}{D^e}\right)\widetilde{D_X t^e} \tag{B.74}$$

$$\widetilde{prem_{Nt}} = \left(\frac{1}{prem_{Nt}}\right)(\widetilde{R_{KNt+1}} - \widetilde{i_t^*} - \widetilde{S_{t+1}} + \widetilde{S}_t - \widetilde{P}_t + \widetilde{P_{t+1}}) \tag{B.75}$$

$$\widetilde{prem_{Xt}} = \left(\frac{1}{prem_{Xt}}\right)(\widetilde{R_{KXt+1}} - \widetilde{i_t^*} - \widetilde{S_{t+1}} + \widetilde{S}_t - \widetilde{P}_t + \widetilde{P_{t+1}}) \tag{B.76}$$

$$\widetilde{lever_{Nt}} = \widetilde{K_{Nt}} + \widetilde{Q_{Nt}} - \widetilde{Z_{Nt}} \tag{B.77}$$

$$\widetilde{lever_{Xt}} = \widetilde{K_{Xt}} + \widetilde{Q_{Xt}} - \widetilde{Z_{Xt}} \tag{B.78}$$

$$\widetilde{Y_{Nt}} = -\rho\widetilde{P_{Nt}} + \rho\widetilde{P_t} + \left(\frac{a(\frac{P_\omega}{P})^{-\rho}}{Y_N}\right)(C\widetilde{C_t} + C_N^e\widetilde{C_{Nt}^e} + C_X^e\widetilde{C_{Xt}^e} + I_N\widetilde{I_{Nt}} + I_X\widetilde{I_{Xt}}) \tag{B.79}$$

$$\widetilde{H_t} = \frac{H_X}{H}\widetilde{H_{Xt}} + \frac{H_N}{H}\widetilde{H_{Nt}} \tag{B.80}$$

$$\widetilde{i_{t+1}} = \left(\frac{1+i}{i}\right)(\mu_\pi \pi P(\widetilde{P_t} - \widetilde{P_{t-1}})) + (\mu_s \frac{S}{\bar{S}}\widetilde{S_t}) + \vartheta_t \tag{B.81}$$

Exogenous Shocks

$$\widetilde{i_t^*} = \rho_i \widetilde{i_{t-1}^*} + ei^* \tag{B.82}$$

$$\widetilde{\vartheta_t} = \rho_\vartheta \widetilde{\vartheta_{t-1}} + e\vartheta \tag{B.83}$$

Appendix C

Appendices to Chapter 4

C.1 Model Equations

C.1.1 Emerging Market Economy (Periphery country)

Price dispersion measure

$$\chi_t^e = \phi \chi_{t-1}^e \pi_t^{ppi,e(\sigma_p)} + (1-\phi)\pi_t^{*,e(-\sigma_p)} \tag{C.1}$$

Firm optimal adjusting price

$$\pi_t^{*,e} = \frac{X_{1,t}^e}{X_{2,t}^e} \tag{C.2}$$

Calvo numerator definition

$$X_{1,t}^e = Y_t^e MC_t^e + \phi \Lambda_{t+1}^e \pi_t^{ppi,e(\sigma_p)} X_{1,t+1}^e \tag{C.3}$$

Calvo denominator definition

$$X_{2,t}^e = Y_t^e P_t^e \frac{\sigma_p - 1}{\sigma_p} + \phi \Lambda_{t+1}^e \pi_t^{ppi,e(\sigma_p-1)} X_{2,t+1}^e \tag{C.4}$$

Price level expression (indirectly marginal cost)

$$1 = \phi(\pi_t^{ppi,e(\sigma_p - 1)}) + (1-\phi)\pi_t^{*,e(1-\sigma_p)} \tag{C.5}$$

Euler equation

$$\Lambda_{t+1}^e R_t^* \frac{RER_{t+1}}{\pi_{t+1}^c RER_t} = 1 \tag{C.6}$$

Definition of discount factor

$$\Lambda_t^e = \beta \left(\frac{C_t^e}{C_{t-1}^e} \right)^{-\sigma} \tag{C.7}$$

Interest rate EME

$$R_t^e = \frac{\pi_{t+1}^e}{\Lambda_{t+1}^e} \tag{C.8}$$

Gross return on capital, taking into account the marginal rate of return on capital r_t^e

$$R_{k,t}^e = \xi_t^e \left(\frac{\alpha M C_t^e Y_t^e}{Q_{t-1}^e K_{t-1}^e \xi_t^{e(\alpha+1)}} + \frac{(1-\delta)Q_t^e}{Q_{t-1}^e} \right) \tag{C.9}$$

EME price level

$$1 = \left(\nu_e P_t^{e(1-\eta)} + (1-\nu_e) \left(RER_t P_t^{c(1-\eta)} \right) \right)^{\frac{1}{1-\eta}} \tag{C.10}$$

CPI inflation measures

$$\pi_t^e = \pi_t^{ppi,e} \frac{P_{t-1}^e}{P_t^e} \tag{C.11}$$

Labour market clearing condition

$$A_t^e (1-\alpha) M C_t^e (\xi_t K_{t-1}^e)^\alpha C_t^{e(-\sigma)} = H_t^{e(\psi+\alpha)} P_t^e \tag{C.12}$$

Accumulation law of capital

$$K_t^e = I_t^e + (1-\delta)\xi_t^e K_{t-1}^e \tag{C.13}$$

assuming an AR(1) process for capital shock

$$\xi_t^e = \rho_\xi \xi_{t-1}^e + \epsilon_{\xi e}$$

Asset pricing equations / investment Euler equation

$$Q_t^e = 1 + \frac{\zeta}{2}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right)^2 + \zeta \frac{I_t^e}{I_{t-1}^e}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right) - \Lambda_{t+1}^e \zeta \left(\frac{I_{t+1}^e}{I_t^e}\right)^2 \left(\frac{I_{t+1}^e}{I_t^e} - 1\right) \tag{C.14}$$

Household's aggregate budget constraint

$$C_t^e + B_t^e RER_t = Y_t^e P_t^e - \alpha A_t^e MC_t^e K_{t-1}^{e(\alpha)} H_{t-1}^{e(1-\alpha)} + Q_t^e I_t^e - I_t^e \left(1 + \frac{\zeta}{2}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right)^2\right) + (1-\theta)(1-\Gamma_t) R_{k,t}^e Q_{t-1}^e K_{t-1}^e - \delta_T Q_{t-1}^e K_t^e + RER_t \frac{R_{t-1}^*}{\pi_t^c} B_{t-1}^e \tag{C.15}$$

Resource constraint / goods market clearing condition

$$Y_t^e \chi_t^e = A_t^e (\xi_t^e K_{t-1}^e)^\alpha H_t^{e(1-\alpha)} \tag{C.16}$$

Aggregate demand for EME goods

$$Y_t^e = \nu^e P_t^{e(-\eta)} \left(C_t^e + I_t^e \left(1 + \frac{\zeta}{2}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right)^2\right)\right) + (1-\nu^c)\frac{1-n}{n}\left(\frac{P_t^e}{RER_t}\right)^{(-\eta)} \left(C_t^c + I_t^c \left(1 + \frac{\zeta}{2}\left(\frac{I_t^c}{I_{t-1}^c} - 1\right)^2\right)\right) \tag{C.17}$$

BOP equation / capital inflows

$$capflow_t = V_{t+1}^e - R_{b,t-1} V_t^e - B_{t+1}^e + B_t^e R_{t-1}^* \tag{C.18}$$

Monetary policy

$$R_t^e = R_{t-1}^{e(\lambda_r)} \left(\left(\frac{\pi_{obj}}{\beta}\frac{\pi_t^e}{\pi_{obj}}\right)^{\lambda_p} (Y_t^e - Y_{t-1}^e)^{\lambda_y}\right)^{(1-\lambda_r)} \rho_t^{mp,e} \tag{C.19}$$

Optimal lending contract between center country banks and EME banks

$$\Lambda^e_{t+1}(1-\theta+\theta\alpha^{v,e}_{t+1})(1-\Gamma_{t+1})R^e_{k,t+1}+\varphi_t\left(R^e_{k,t+1}\Gamma_{t+1}\frac{RER_t}{RER_{t+1}}-\frac{R_{b,t}}{\pi^c_{t+1}}\right)-\gamma^e_t\kappa^e=0 \quad (C.20)$$

where

$$\Gamma_t=\frac{RER_tR_{b,t-1}}{\pi^c_tR^e_{k,t}}\frac{V^e_{t-1}}{Q^e_{t-1}K^e_{t-1}}$$

$$\varphi_t=\frac{\alpha^{v,e}_t(1-\gamma^e_t)}{R_{b,t}/\pi^c_{t+1}}$$

Envelope condition

$$\alpha^{v,e}_t(1-\gamma^e_t)\frac{RER_t}{RER_{t+1}}-\Lambda^e_{t+1}(1-\theta+\theta\alpha^{v,e}_{t+1})R_{b,t}=0 \quad (C.21)$$

Incentive compatibility constraint for EME bank (using the fact that $\alpha^{v,e}_tN^e_t=J^e_t$):

$$\alpha^{v,e}_tN^e_t-\kappa^e_ZQ^e_tK^e_t=0 \quad (C.22)$$

The aggregate net worth of EME bank:

$$N^e_t=\theta\left(R^e_{k,t}Q^e_{t-1}K^e_{t-1}-\frac{R_{b,t-1}}{\pi^c_{t+1}}V^e_{t-1}RER_t\right)+\delta_TQ^e_tK^e_{t-1} \quad (C.23)$$

Resource constraint for EME bank:

$$Q^e_tK^e_t=N^e_t+RER_tV^e_t \quad (C.24)$$

C.1.2 Advanced Economy (Core country)

Price dispersion measure

$$\chi^c_t=\phi\chi^c_{t-1}\pi^{ppi,c(\sigma_p)}_t+(1-\phi)\pi^{*,c(-\sigma_p)}_t \quad (C.25)$$

Firm optimal adjusting price

$$\pi^{*,c}_t=\frac{X^c_{1,t}}{X^c_{2,t}} \quad (C.26)$$

Calvo numerator definition

$$X^c_{1,t} = Y^c_t MC^c_t + \phi \Lambda^c_{t+1} \pi_t^{ppi,c(\sigma_p)} X^c_{1,t+1} \tag{C.27}$$

Calvo denominator definition

$$X^c_{2,t} = Y^c_t P^c_t \frac{\sigma_p - 1}{\sigma_p} + \phi \Lambda^c_{t+1} \pi_t^{ppi,c(\sigma_p - 1)} X^c_{2,t+1} \tag{C.28}$$

Price level expression (indirectly marginal cost)

$$1 = \phi(\pi_t^{ppi,c(\sigma_p - 1)}) + (1 - \phi)\pi_t^{*,c(1-\sigma_p)} \tag{C.29}$$

Euler equation

$$\frac{\Lambda^c_{t+1} R^*_t}{\pi^c_{t+1}} = 1 \tag{C.30}$$

Definition of discount factor

$$\Lambda^c_t = \beta \left(\frac{C^c_t}{C^c_{t-1}} \right)^{-\sigma} \tag{C.31}$$

Gross return on capital, taking into account the marginal rate of return on capital r^c_t

$$R^c_{k,t} = \xi^c_t \left(\frac{\alpha MC^c_t Y^c_t}{Q^c_{t-1} K^c_{t-1} \xi_t^{c(\alpha+1)}} + \frac{(1-\delta) Q^c_t}{Q^c_{t-1}} \right) \tag{C.32}$$

AE price-level

$$1 = \left(\nu_c P_t^{c(1-\eta)} + (1 - \nu_c) \frac{1}{RER_t} P_t^{e,(1-\eta)} \right)^{\frac{1}{1-\eta}} \tag{C.33}$$

CPI inflation measures

$$\pi^c_t = \pi_t^{ppi,c} \frac{P^c_{t-1}}{P^c_t} \tag{C.34}$$

Labour market clearing condition

$$A_t^c(1-\alpha)MC_t^c(\xi_t K_{t-1}^c)^\alpha C_t^{c(-\sigma)} = H_t^{c(\psi+\alpha)} P_t^c \tag{C.35}$$

Accumulation law of capital

$$K_t^c = I_t^c + (1-\delta)\xi_t^c K_{t-1}^c \tag{C.36}$$

assuming an AR(1) process for capital shock

$$\xi_t^c = \rho_\xi \xi_{t-1}^c + \epsilon_{\xi c}$$

Asset pricing equations / investment Euler equation

$$Q_t^c = 1 + \frac{\zeta}{2}\left(\frac{I_t^c}{I_{t-1}^c} - 1\right)^2 + \zeta \frac{I_t^c}{I_{t-1}^c}\left(\frac{I_t^c}{I_{t-1}^c} - 1\right) - \Lambda_{t+1}^c \zeta \left(\frac{I_{t+1}^c}{I_t^c}\right)^2 \left(\frac{I_{t+1}^c}{I_t^c} - 1\right) \tag{C.37}$$

Resource constraint / goods market clearing condition

$$Y_t^c \chi_t^c = A_t^c(\xi_t^c K_{t-1}^c)^\alpha H_t^{c(1-\alpha)} \tag{C.38}$$

Aggregate demand for EME goods

$$\begin{aligned} Y_t^c = \nu^c P_t^{c(-\eta)} \left(C_t^c + I_t^c \left(1 + \frac{\zeta}{2}\left(\frac{I_t^c}{I_{t-1}^c} - 1\right)^2\right)\right) + \\ (1-\nu^e)\frac{n}{1-n}\left(P_t^c RER_t\right)^{(-\eta)} \left(C_t^e + I_t^e \left(1 + \frac{\zeta}{2}\left(\frac{I_t^e}{I_{t-1}^e} - 1\right)^2\right)\right) \end{aligned} \tag{C.39}$$

Monetary policy

$$R_t^* = R_{t-1}^{*(\lambda_r)} \left(\left(\frac{\pi_{obj}}{\beta}\frac{\pi_t^c}{\pi_{obj}}\right)^{\lambda_p} (Y_t^c - Y_{t-1}^c)^{\lambda_y}\right)^{(1-\lambda_r)} \rho_t^{mp,c} \tag{C.40}$$

Optimal choice of assets by centre country banks

$$\Lambda_{t+1}^c(1-\theta+\theta\alpha_{t+1}^{\upsilon,c})\left(R_{k,t+1}^c - \frac{R_t^*}{\pi_{t+1}^c} - \frac{n}{1-n}\frac{V_t^e}{\omega_t}\left(R_{k,t+1}^c - \frac{R_{b,t}}{\pi_{t+1}^c}\right)\right) = \kappa_c \gamma_t^c \tag{C.41}$$

where ω_t denotes total assets of centre country banks.

Centre country banks efficient investment in EME banks (asset pricing equation):

$$\Lambda^c_{t+1}(1-\theta+\theta\alpha^{v,c}_{t+1})\left(R^c_{k,t+1}-\frac{R_{b,t}}{\pi^c_{t+1}}\right)=0 \tag{C.42}$$

Envelope condition for centre country optimal plan:

$$-\alpha^{v,c}_t(1-\gamma^c_t)+\frac{R^*_t\Lambda^c_{t+1}(1-\theta+\theta\alpha^{v,c}_{t+1})}{\pi^c_{t+1}}=0 \tag{C.43}$$

Incentive compatibility constraint:

$$\alpha^{v,c}_t N^c_t-\omega_t\kappa_c=0 \tag{C.44}$$

Net worth of centre country banks:

$$N^c_t=\theta\left(\left(R^c_{k,t}-\frac{R^*_{t-1}}{\pi^c_t}\right)\omega_{t-1}-\frac{n}{1-n}V^e_{t-1}\left(R^c_{k,t}-\frac{R_{b,t-1}}{\pi^c_t}\right)+\frac{R^*_{t-1}}{\pi^c_t}N^c_{t-1}\right)+K^c_{t-1}\delta_T \tag{C.45}$$

Resource constrain for centre country banks:

$$V^e_t+Q^c_tK^c_t=N^c_t+B^c_t \tag{C.46}$$

Definition of total assets for centre country:

$$\omega_t=\frac{n}{1-n}V^e_t+Q^c_tK^c_t \tag{C.47}$$

Bibliography

Agénor, P.-R. and Jia, P. (2017). Macroprudential policy coordination in a currency union'. *Centre for Growth and Business Cycle Research Discussion Paper Series*, (235).

Agénor, P.-R., Kharroubi, E., Gambacorta, L., Lombardo, G., and Pereira da Silva, L. A. (2017). The international dimensions of macroprudential policies. *Bank for International Settlements Working Papers*, (643).

Ahmed, S. and Zlate, A. (2014). Capital flows to emerging market economies: a brave new world? *Journal of International Money and Finance*, 48:221–248.

Aizenman, J., Binici, M., and Hutchison, M. M. (2014). The transmission of Federal Reserve tapering news to emerging financial markets. *NBER Working Paper*, (19980).

Alpanda, S. and Kabaca, S. (2015). International spillovers of large-scale asset purchases. *Bank of Canada Working Paper*, (2015-2).

Avdjiev, S., McCauley, R. N., and Shin, H. S. (2016). Breaking free of the triple coincidence in international finance. *Economic Policy*, 31(87):409–451.

Azis, I. J. and Shin, H. S. (2015). *Managing Elevated Risk: Global Liquidity, Capital Flows, and Macroprudential Policy - An Asian Perspective.* Asian Development Bank. Springer, Singapore.

Banerjee, R., Devereux, M. B., and Lombardo, G. (2016). Self-oriented monetary policy, global financial markets and excess volatility of international capital flows. *Journal of International Money and Finance*, 68:275–297.

Barroso, J. B. R., da Silva, L. A. P., and Sales, A. S. (2015). QE and related capital flows into Brazil: Measuring its effects and transmission channels through a rigorous counterfactual evaluation. *Journal of International Money and Finance*, 67:102–122.

Bauer, M. D. and Neely, C. J. (2014). International channels of the fed's unconventional monetary policy. *Journal of International Money and Finance*, 44:24–46.

Bernanke, B. (2005). The global saving glut and the US current account deficit. *Speech Collection of the Board of Governors of the Federal Reserve System*, (77).

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics*, 1:1341–1393.

Bernanke, B. S. and Kuttner, K. N. (2005). What explains the stock market's reaction to federal reserve policy? *The Journal of finance*, 60(3):1221–1257.

Billio, M., Getmansky, M., Lo, A. W., and Pelizzon, L. (2012). Econometric measures of connectedness and systemic risk in the finance and insurance sectors. *Journal of Financial Economics*, 104(3):535–559.

BIS (2011). Global liquidity-concept, measurement and policy implications. *Comittee on the Global Financial System Papers*, 45.

Blinder, A. S. (2010). Quantitative Easing: Entrance and exit strategies (digest summary). *Federal Reserve Bank of St. Louis Review*, 92(6):465–479.

Borio, C. E. (2011). Central banking post-crisis: What compass for uncharted waters? *BIS Working Papers*, (353).

Borio, C. E. and Disyatat, P. (2011). Global imbalances and the financial crisis: Link or no link? *BIS Working Papers*, (346).

Bruno, V. and Shin, H. S. (2015a). Capital flows and the risk-taking channel of monetary policy. *Journal of Monetary Economics*, 71:119–132.

Bruno, V. and Shin, H. S. (2015b). Cross-border banking and global liquidity. *The Review of Economic Studies*, 82(2):535–564.

Brzoza-Brzezina, M. and Kolasa, M. (2013). Bayesian evaluation of dsge models with financial frictions. *Journal of Money, credit and banking*, 45(8):1451–1476.

Buch, C. M., Koch, C., and Koetter, M. (2016). Crises and rescues: Liquidity transmission through international banks. *BIS Working Papers*, (576).

Carlstrom, C. T. and Fuerst, T. S. (1997). Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *The American Economic Review*, pages 893–910.

Caruana, J. (2012). International monetary policy interactions: Challenges and prospects. In *Speech at the CEMLA-SEACEN Conference, Uruguay.*

Caruana, J. (2014). Global liquidity: Where it stands, and why it matters. In *BIS Distinguished Lecture at Goethe University, Frankfurt, 5 March 2014.*

Cerutti, E., Claessens, S., and Laeven, L. (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability 28*, pages 203–224.

Cetorelli, N. and Goldberg, L. S. (2011). Global banks and international shock transmission evidence from the crisis. *IMF Economic Review*, 59(1):41–76.

Cetorelli, N. and Goldberg, L. S. (2012a). Banking globalization and monetary transmission. *The Journal of Finance*, 67(5):1811–1843.

Cetorelli, N. and Goldberg, L. S. (2012b). Follow the money: Quantifying domestic effects of foreign bank shocks in the great recession. *The American Economic Review*, 102(3):213–218.

Cetorelli, N. and Goldberg, L. S. (2012c). Liquidity management of US global banks: Internal capital markets in the great recession. *Journal of International Economics*, 88(2):299–311.

Chen, H., Cúrdia, V., and Ferrero, A. (2012a). The macroeconomic effects of large-scale asset purchase programmes. *The Economic Journal*, 122(564):F289–F315.

Chen, Q., Filardo, A., He, D., and Zhu, F. (2015). Financial crisis, US unconventional monetary policy and international spillovers. *Journal of International Money and Finance.*

Chen, Q., Filardo, A. J., He, D., and Zhu, F. (2012b). International spillovers of central bank balance sheet policies. *BIS Paper*, (66).

Chinn, M. D. (2013). Global spillovers and domestic monetary policy. *BIS Working Paper*, (436).

Christensen, I. and Dib, A. (2008). The financial accelerator in an estimated new keynesian model. *Review of Economic Dynamics*, 11(1):155–178.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

Chua, W. S., Endut, N., Khadri, N., and Sim, W. H. (2013). Global monetary easing: spillovers and lines of defence. Technical report, Bank Negara Malaysia Working Paper Series.

Conover, C. M., Jensen, G. R., and Johnson, R. R. (1999). Monetary environments and international stock returns. *Journal of Banking & Finance*, 23(9):1357–1381.

d'Amico, S., English, W., López-Salido, D., and Nelson, E. (2012). The Federal Reserve's large-scale asset purchase programmes: Rationale and effects. *The Economic Journal*, 122(564):F415–F446.

De Haas, R. and Van Horen, N. (2012). Running for the exit? International bank lending during a financial crisis. *Review of Financial Studies*, 26(1):244–285.

Devereux, M. B., Lane, P. R., and Xu, J. (2006). Exchange rates and monetary policy in emerging market economies. *Economic Journal*, 116(511):478–506.

Didier, T., Love, I., and Martínez Pería, M. S. (2012). What explains comovement in stock market returns during the 2007–2008 crisis? *International Journal of Finance & Economics*, 17(2):182–202.

Diebold, F. X. and Yilmaz, K. (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, 119(534):158–171.

Diebold, F. X. and Yılmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics*, 182(1):119–134.

Domanski, D., Fender, I., and McGuire, P. (2011). Assessing global liquidity. *BIS Quarterly Review*.

Eichengreen, B. (2013). Currency war or international policy coordination. *Journal of Policy Modeling*, 35(3):425–433.

Eichengreen, B. and Gupta, P. (2015). Tapering talk: The impact of expectations of reduced Federal Reserve security purchases on emerging markets. *Emerging Markets Review*, 25:1–15.

Eichengreen, B., Rose, A. K., Wyplosz, C., Dumas, B., and Weber, A. (1995). Exchange market mayhem: The antecedents and aftermath of speculative attacks. *Economic Policy*, pages 249–312.

Fratzscher, M., Lo Duca, M., and Straub, R. (2013). On the international spillovers of US QE. *ECB Working Paper Series*, (1557).

Frey, R. and Kerl, C. (2015). Multinational banks in the crisis: Foreign affiliate lending as a mirror of funding pressure and competition on the internal capital market. *Journal of Banking & Finance*, 50:52–68.

Gabaix, X. and Maggiori, M. (2015). International liquidity and exchange rate dynamics. *The Quarterly Journal of Economics*, 130(3):1369–1420.

Gagnon, J., Raskin, M., Remache, J., Sack, B., et al. (2011). The financial market effects of the federal reserve's large-scale asset purchases. *international Journal of central Banking*, 7(1):3–43.

Galema, R., Koetter, M., and Liesegang, C. (2016). Lend global, fund local? Price and funding cost margins in multinational banking. *Review of Finance*, 20(5):1981–2014.

Gelain, P., Rodriguez-Palenzuela, D., and Világi, B. (2009). An estimated dsge model with financial frictions. *European Central Bank, Mimeo.*

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and banking in a DSGE model of the Euro Area. *Journal of Money, Credit and Banking*, 42(s1):107–141.

Gertler, M. (1988). Financial structure and aggregate economic activity: an overview. *NBER Working Papers*, (2559).

Gertler, M., Gilchrist, S., and Natalucci, F. M. (2007). External constraints on monetary policy and the financial accelerator. *Journal of Money, Credit and Banking*, 39(2-3):295–330.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34.

Gertler, M., Kiyotaki, N., and Queralto, A. (2012). Financial crises, bank risk exposure and government financial policy. *Journal of Monetary Economics*, 59:S17–S34.

Gray, C. (2013). Responding to a monetary superpower: Investigating the behavioral spillovers of US monetary policy. *Atlantic Economic Journal*, 41(2):173–184.

Greenwood-Nimmo, M., Nguyen, V. H., and Shin, Y. (2015a). Measuring the connectedness of the global economy. *Melbourne Institute Working Paper*, 7(15).

Greenwood-Nimmo, M., Nguyen, V. H., and Shin, Y. (2015b). Quantifying informational linkages in a global model of currency spot markets. *Melbourne Institute Working Paper*, 17(14).

Haas, R. and Lelyveld, I. (2014). Multinational banks and the global financial crisis: Weathering the perfect storm? *Journal of Money, Credit and Banking*, 46(s1):333–364.

Haberis, A. and Lipinska, A. (2012). International policy spillovers at the zero lower bound.

Haldane, A. G. (2011). The big fish small pond problem. *Speech at the Institute for New Economic Thinking Annual Conference, Bretton Woods, New Hampshire, 9 April 2011.*

Harmanta, H., Oktiyanto, F., Purwanto, N. M. A., Rachmanto, A., et al. (2014). Monetary macroprudential policy mix under financial frictions mechanism with DSGE model. Technical report, EcoMod.

Hausmann, R., Panizza, U., and Stein, E. (2001). Why do countries float the way they float? *Journal of Development Economics*, 66(2):387–414.

Hofmann, B. and Bogdanova, B. (2012). Taylor Rules and monetary policy: A global 'great deviation'? *BIS Quarterly Review September.*

IMF, I. M. F. (2011). Recent experiences in managing capital inflows—cross-cutting themes and possible policy framework. *IMF Paper*, February.

Jain-Chandra, S. and Unsal, D. (2012). The effectiveness of monetary transmission under capital controls: Evidence from Asia. *IMF Working Paper*, (295).

Keen, B. and Wang, Y. (2007). What is a realistic value for price adjustment costs in new keynesian models? *Applied Economics Letters*, 14(11):789–793.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *The Journal of Political Economy*, 105(2):211–248.

Koop, G., Pesaran, M. H., and Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74(1):119–147.

Lavigne, R., Sarker, S., Vasishtha, G., et al. (2014). Spillover effects of QE on emerging-market economies. *Bank of Canada Review*, 2014(Autumn):23–33.

Levine, P. and Lima, D. (2015). Policy mandates for macro-prudential and monetary policies in a new keynesian framework. *ECB Working Paper Series*, (1784).

Levine, R. (2005). Finance and growth: theory and evidence. *Handbook of economic growth*, 1:865–934.

Lim, C. H., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and Wu, X. (2011). Macroprudential policy: What instruments and how to use them? Lessons from country experiences. *IMF Working Paper*, 11(238).

MacDonald, M. (2017). International capital market frictions and spillovers from quantitative easing. *Journal of International Money and Finance*, 70:135–156.

Madeira, C. and Madeira, J. (2015). Dissent in fomc meeting and the announcement drift. *Working Papers Central Bank of Chile*, 749.

McCracken, M. W. and Ng, S. (2015). FRED-MD: A monthly database for macroeconomic research. *Journal of Business & Economic Statistics*, 34(4).

Mendoza, E. G., Quadrini, V., and Rios-Rull, J.-V. (2009). Financial integration, financial development, and global imbalances. *Journal of Political Economy*, 117(3):371–416.

Merola, R. (2010). Optimal monetary policy in a small open economy with financial frictions. *Deutsche Bundesbank Discussion Paper Series*, (2010,01).

Miranda-Agrippino, S. and Rey, H. (2015). World asset markets and the global financial cycle. *NBER Working Paper Series*, (21722).

Moreno, R., Mihaljek, D., Villar, A., and Takats, E. (2010). The global crisis and financial intermediation in emerging market economies. *BIS Papers*, (54).

Olson, E. and Young, A. T. (2015). Discretionary monetary policy, quantitative easing and the decline in US labor share. *Economics and Business Letters*, 4(2):63–78.

Ozkan, G. and Unsal, F. (2017). It is not your fault, but it is your problem: Global financial crisis and emerging markets. *Oxford Economic Papers*, 69(3):591–611.

Pesaran, H. H. and Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters*, 58(1):17–29.

Pesaran, M. H., Schuermann, T., and Weiner, S. M. (2004). Modeling regional interdependencies using a global error-correcting macroeconometric model. *Journal of Business & Economic Statistics*, 22(2):129–162.

Pesaran, M. H., Shin, Y., and Smith, R. J. (2000). Structural analysis of VECM with exogenous I (1) variables. *Journal of Econometrics*, 97(2):293–343.

Popov, A. and Udell, G. F. (2012). Cross-border banking, credit access, and the financial crisis. *Journal of International Economics*, 87(1):147–161.

Rey, H. (2015). Dilemma not trilemma: the global financial cycle and monetary policy independence. *NBER Working Paper*, (21162).

Rotemberg, J. J. (1982). Sticky prices in the united states. *Journal of Political Economy*, 90(6):1187–1211.

Sahay, R., Arora, V., Arvanitis, T., Faruqee, H., N'Diaye, P., Griffoli, T. M., et al. (2014). Emerging market volatility: Lessons from the taper tantrum. *IMF Staff Discussion Notes*, (14/9).

Saito, M. (2004). Armington elasticities in intermediate inputs trade: a problem in using multilateral trade data. *Canadian Journal of Economics/Revue canadienne d'économique*, 37(4):1097–1117.

Schmitt-Grohé, S. and Uribe, M. (2003). Closing small open economy models. *Journal of International Economics*, 61(1):163–185.

Schmitt-Grohé, S. and Uribe, M. (2005). Optimal fiscal and monetary policy in a medium-scale macroeconomic model. *NBER Macroeconomics Annual*, 20:383–425.

Schoenmaker, D. (2011). The financial trilemma. *Economics Letters*, 111(1):57–59.

Shin, H. S. (2016). Global liquidity and procyclicality. *BIS - World Bank Conference, 'The state of economies, the state of the world'.*

Smith, L. and Galesi, A. (2014). GVAR Toolbox 2.0. *Toolbox is available at: https://sites. google. com/site/gvarmodelling/gvar-toolbox/download.*

Sousa, J. and Zaghini, A. (2008). Monetary policy shocks in the Euro Area and global liquidity spillovers. *International Journal of Finance & Economics*, 13(3):205–218.

Takáts, E. and Temesvary, J. (2016). The currency dimension of the bank lending channel in international monetary transmission. *BIS Working Papers*, (600).

Takáts, E. and Vela, A. (2014). International monetary policy transmission. *BIS Working Papers*, (78b).

Tarashev, N., Avdjiev, S., and Cohen, B. (2016). International capital flows and financial vulnerabilities in emerging market economies: analysis and data gaps. *Note submitted to the G20 International Financial Architecture Working Group, Bank for International Settlements, August.*

Taylor, J. B. (2013). International monetary coordination and the great deviation. *Journal of Policy Modeling*, 35(3):463–472.

Tintchev, M. K. (2013). Connected to whom? International interbank borrowing during the global crisis. *IMF Working Paper*, (14).