Essays on Monetary and International Macroeconomics

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Part I

Introduction

Summary

This dissertation contains three essays on monetary policy, dynamics of the interest rates and international spillover patterns across economies. Each of the essays is self-contained and independent of the others. Nevertheless, they all look from different angles at the transmission channels between monetary policy, asset prices and the real economy.

The objective of the first essay is to examine the effects of monetary policy and its interaction with financial regulation within a micro-founded macroeconometric framework for a closed economy with a heterogeneous banking system facing a period of very low interest rates. This paper enriches the existing research on the effects of unconventional monetary policy instruments. The original contribution comes from the analysis of the interplay between monetary policy and banking regulation and from the examination of the role of agents' expectations for the effectiveness of unconventional monetary policy tools. My main results point at a rather limited impact of the expectations. Overall, the findings indicate that the optimal monetary policy should embrace qualitative monetary easing for price stability, liquidity injections when addressing GDP growth and capital support to enhance the stability of the financial system. In the presence of the lower bound, which considerably disrupts positive effects of liquidity injections, the role of expectations for the effects of the monetary policy becomes more important.

In the next essay of my thesis, I turn my attention to one of the transmission channels of the monetary policy – interest rates – and argue that openness is crucial for understanding the dynamics of the term structure. In my essay, I combine the macroeconomic viewpoint of the term structure with a modelling strategy of empirical literature on international business cycles and economic linkages between countries. I evaluate the yield curve by means of a structural cointegrated vector autoregressive model nested within a no-arbitrage affine term structure setup. The proposed model extends the term structure literature, since it evaluates the relationship between macroeconomic aggregates and interest rates for an open economy in a multilateral setup. In an empirical application using Swiss data, I show that the model fits well the yield curve in-sample and has a sound ability to forecast interest rates out-of-sample. I document empirically that external macroeconomic variables contain a lot of information that helps to explain the dynamics of the domestic term structure. In addition, I find that the model is able to account for the expectations hypothesis; it also replicates the empirical findings of the forward premium anomaly and reconciles the uncovered interest rate parity implications once the model implied exchange rate risk premia are considered.

The last essay is concerned with the dynamics of the co-movement among macroeconomic aggregates across countries. In this essay, I pursue the research question of the degree of convergence or decoupling amongst economies. The original contribution of my essay is to put this question into the Global VAR (GVAR) framework. Contrary to previous studies, the model contains both macroeconomic and financial variables, and it includes measures of financial and trade-based interdependencies between economies.

Furthermore, it incorporates feedback between macroeconomic variables and time-varying weights and thus accounts for the dynamic character of relations between economies. In this essay, I report two major results. First, the development in international financial markets and cross-border trade activity expands the transmission of shocks abroad and amplifies business cycle fluctuations to regions where the integration is greater, especially as a result of asset price movements. Impulse responses of real sectors tend to support the idea of decoupling of economies, showing evidence of slightly different paths of economic performance across regions. Second, financial linkages tend to substantially alter the dynamics of the macroeconomic aggregates across economies by adding moderation and disattachement in propagation of shocks among regions.

Zusammenfassung

In meiner Dissertation beschäftige ich mich mit aktuellen Fragestellungen der internationalen und monetären Makroökonomie.

Das erste Kapitel meiner Doktorarbeit, verfasst in einer Zusammenarbeit, zielt auf die Analyse der Effekte der Geldpolitik und ihrer Wechselwirkung mit der Bankregulierung im Rahmen eines mikroökonomisch fundierten Modells für die geschlossene Wirtschaft mit heterogenem Banksektor ab, die sich in einer Periode von niedrigen Zinsen befindet. Dieses Kapitel trägt zu der wachsenden Literatur über DSGE-Modelle bei, die sich mit der Struktur des Bankensektors befasst und dessen Auswirkung auf die Produktionswirtschaft misst und analysiert. Die Arbeit steuert auch der zurzeit schnell wachsende Literatur über nicht konventionelle monetäre Maßnahmen der Zentralbanken neue Ideen bei. Der Originalbeitrag bezieht sich auf die Analyse des Zusammenspiels zwischen Geldpolitik und Bankregulierung, und insbesondere auf die Untersuchung der Rolle von Erwartungsbildung bezüglich der künftigen Politik der Zentralbanken im Hinblick auf Effektivität der nicht konventionellen geldpolitischen Instrumente.

In diesem Kapitel steht ein heterogener Bankensektor, repräsentiert durch Einlagen- und Kreditbanken, im Zentrum des Models. Durch die Annahme, dass die Kreditbanken insolvent werden können, entsteht in der modellierten Wirtschaft ein Effekt des Finanzhebels, der die Folgen der Schocks zu verstärken versucht. Die Möglichkeit der Insolvenz der Kreditbanken erlaubt die Wichtigkeit der Sicherheit auf dem Interbankmarkt in den Vordergrund zu stellen und die destabilisierenden Auswirkungen der möglichen Liquiditätsengpässe zu erkunden. Des Weiteren verschafft ein solcher Aufbau des Bankensektors die Möglichkeit, die Bedeutung der Bilanzen der Banken zu unterstreichen und die Wirksamkeit der Änderungen im Regelwerk der Bankenregulierung zu erforschen. Diese Änderungen enthalten zusätzliche Kapitalanforderungen für Banken, einen antizyklisch festgelegten Kapitalquotienten und eine Gesamtkapitalversicherung der Finanzinstitute. Insgesamt fasst mein DSGE-Modell zehn strukturelle Schocks um; die Finanzschocks bestehen aus direkten Geldspritzen (sog. "Quantitative Easing"), Wertpapierumtauschgeschäften (sog. "Qualitative Easing"), direkten Krediten der Zentralbank an die Produktionsfirmen, Kapitalerhöhungen für die Banken und aus Besteuerung der Einlagen.

Das DSGE-Modell in diesem Kapitel ist von Preisniveaustarrheit gekennzeichnet. Es fasst Haushalte, Banken, Produktionsunternehmen und eine Zentralbank um. Der Bankensektor besteht aus Einlagen- und Kreditbanken, die zusammen den Interbankmarkt darstellen. Die Zentralbank führt sowohl die übliche sich auf Preisstabilität beziehende als auch die nicht konventionelle Geldpolitik aus. Es wird aus Vereinfachungsgründen zusätzlich angenommen, dass die Zentralbank die Rolle eine Regulierungsbehörde innehat, indem sie die Banken bezüglich der Kapitalanforderungen unterrichtet und die Besteuerung der Haushalte anordnen kann.

Die Haushalte nutzen ihre Ressourcen, um zu konsumieren oder zu investieren (anlegen). Sie erhalten Entgelt für die geleistete Arbeit, platzieren Einlagen bei den Einlagebanken, können jedoch keine Kredite aufnehmen. Ihre Einlagen können unter Umständen von der Zentralbank besteuert werden. Im stabilen Zustand des Modells (sog. "Steady State") beträgt dieser Steuersatz null und er hat insofern keine weitere Auswirkung auf die Haushalte. Ein positiver Steuersatz soll dagegen die Höhe der Bankeinlagen vermindern und den Konsum anregen. In Folge der Einlagensteuer kommt eine Stärkung der Binnennachfrage zustande, die reell gesehen die untere Grenze für den Nominalzinssatz der Zentralbank zu umgehen vermag.

Produktionsunternehmen sind risikoneutral, legen Preise für ihre Produkte fest, sind Arbeitgeber für die Haushalte und nehmen Kredite bei den Kreditbanken auf, um eigenes Produktionskapital aufzubauen. Zum Aufbau des Kapitals können auch Mittel von der Zentralbank verwendet werden, sofern es den Unternehmen nicht möglich ist, aufgrund von Liquiditätsengpässen Kredite bei Banken zu bekommen. Die Preisstarrheit erfolgt durch den Rotemberg-Kostenfaktor. Die Unternehmen sind monopolistische Konkurrenten mit nach unten abfallenden Nachfragefunktionen. Sie produzieren gemäß der Cobb-Douglas Produktionsfunktion.

Sowohl Einlagen- als auch Kreditbanken sind risikoscheu. Einlagenbanken sammeln Einlagen von den Haushalten und bieten den Kreditbanken Kredite auf dem Interbankmarkt. Zusätzlich investieren sie ihre Mittel in ein exogen bestimmtes Kapitalmarktportfolio. Einlagenbanken ziehen zusätzlichen Nutzen aus der Unterhaltung ihres Eigenkapitals über der von der Zentralbank bestimmten Kapitalgrenze, die durch den Kapital- und den Hebelquotienten bestimmt wird. Gleichzeitig müssen Sie jedoch mit Opportunitätskosten des Eigenkapitals rechnen. Das Kapital der Banken wird durch einbehaltene Gewinne akkumuliert; ein kleiner Bestandteil des Kapitals wird als Prämie in die Versicherung eingezahlt, die auf Absicherung der ausgefallenen Kredite an die Kreditbanken abzielt. Zum anderen wird aufgrund der Versicherung eine Möglichkeit für die Banken geöffnet, Kapitalunterstützung seitens der Zentralbank zu erhalten. Diese Kapitalmaßnahmen erfolgen im Falle einer stark Erhöhten Ausfallrate der Kreditbanken und Unternehmen. Die Einlagenbanken können von der Zentralbank zusätzliche Liquidität bekommen; ebenso ist es ihnen möglich, eine Unterstützung in Form von Wertpapierumtauschgeschäften in Anspruch zu nehmen. Die Kreditbanken werden analog zu den Einlagenbanken definiert, mit der Ausnahme, dass sie sich für Insolvenz entscheiden können, d.h. die von den Einlagenbanken gewährten Kredite nicht zurückbezahlen.

Die Zentralbank übt Geldpolitik gemäß einer endogenen Zinsregel aus. In Krisenzeiten kann sie zu "unkonventionellen" Mitteln greifen: Liquiditätsspritzen und Wertpapierumtauschgeschäften, die an Banken und Unternehmen weitergegeben werden können. Zusätzlich kann die Bank eine Einlagensteuer festlegen. Es wird angenommen, dass all diese Maßnahmen in erster Linie durch Einkünfte aus den Versicherungsprämien und Steuererträgen erwirtschaftet werden. Insofern gelten diese Maßnahmen als inflationstreibend, falls sie in ihrem Umfang über den finanzierten Betrag hinausgehen.

Das Modell wird mit Hilfe von US-Daten kalibriert. Die dynamischen Eigenschaften des Modells werden mittels einer Analyse der Impulsantworten erforscht. Darüber hinaus werden Experimente zur Untersuchung der Wirksamkeit der Geldpolitik durchgeführt, in denen Ergebnisse einer Rezession und darauf folgenden Maßnahmen der Zentralbank untersucht werden. Schließlich wird das Modell mittels einer Bayes'schen Methode mit dem Metropolis Algorithmus auf Grundlage der US-Daten für Produktion, Zinssatz der Zentralbank und Inflation geschätzt.

Der innovative Beitrag dieser Arbeit bezieht sich auf mehrere Bereiche. Zum einen, es ist bei Weitem die umfassendste Analyse der unkonventionellen Instrumente, die einer Zentralbank zur Verfügung stehen. Unsere Ergebnisse deuten darauf hin, dass Liquiditätsmaßnahmen am effektivsten sind, ihre Wirkung scheint jedoch von begrenzter Dauer zu sein. Andererseits sind Wertpapierwechselgeschäfte beständiger, führen aber zu niedrigeren Steigerung des Bruttosozialprodukts und Konsums. Kapitalzuführungen verbessern die Stabilität des Bankensystems indem sie die Solvabilität der Banken und Unternehmen stärken. Eine Einlagensteuer funktioniert ähnlich wie eine expansive Geldpolitik. Zum zweiten, erforschen wir die Effekte der Erwertungsbildung auf die Wirksamkeit der Geldpolitik, was uns erlabt, die Fragen der Glaubwürdigkeit und Selbstverpflichtung der Zentralbank zu berücksichtigen. Unsere Hauptergebnisse weisen auf eine begrenzte Rolle der Erwertungsformation für die Effektivität der nicht konventionellen Geldpolitik hin. Wir stellen fest, dass optimale Geldpolitik Wertpapiergeschäfte zur Preisstabilität, Liquiditätszuführungen für das Wirtschaftswachstum und Kapitalzuführungen zur Steigerung der Stabilität des Finanzsystems umfassen soll. Zum dritten, berücksichtigen wir die Beschränkung der Geldpolitik durch die Null-Grenze der Zinssätze. Diese Grenze scheint die nicht konventionelle Geldpolitik wesentlich zu behindern; gleichzeitig trägt sie dazu bei, die Rolle der Erwartungsbildung auf die Wirksamkeit der nicht konventionellen monetären Maßnahmen zu verdeutlichen.

Im nächsten Kapitel meiner Dissertation beschäftige ich mich mit einem der Transmissionsmechanismen für die Geldpolitik, der Zinsstrukturkurve, und belege, dass Offenheit der Wirtschaft von entscheidender Bedeutung für das Verstehen der Dynamik der Zinssätze ist. Insbesondere untersuche ich, wie die von innen und von außen kommenden makroökonomischen Faktoren in einer offenen Wirtschaft die Bewegungen der Zinsstrukturkurve und der Risikoprämien beeinflussen. Aufgrund der Wichtigkeit für die

Verbindung zwischen Geldpolitik, Produktionstätigkeit, Inflation und Wertpapierpreisen, hat sich die Finanzanalyse und die makroökonomische Analyse seit langem dem Studium der Zinsstrukturkurve zugewandt. Die meisten Finanzstudien fokussierten sich primär auf Vorhersagen der Bewegungen der Zinssätze und Wertpapierpreise, und verwendeten dabei sog. latente Faktoren. Solche Modelle sind zwar von einer sehr guten Prognosegüte gekennzeichnet, ihr Nachteil besteht jedoch darin, dass latenten Faktoren keine eindeutige ökonomische Interpretation zugeordnet werden kann. Die Finanzmodelle schaffen es nicht, eine Verbindung zwischen makroökonomischen Größen und Zinssätzen, die selbst ja ein Teil der wirtschaftlichen Umgebung sind, herzustellen. Das gilt vor allem für eine offene Wirtschaft, die sowohl von den Binnen- als auch von den Außenkonjunkturzyklen abhängt, und wo die Entwicklung der Zinssätze von Erwartungen bezüglich makroökonomischer Variablen beeinflusst wird. In diesem Kapitel zeige ich ein Modell der Zinsstrukturkurve, der diese Probleme anspricht und dabei eine hervorragende Prognosegüte aufweist.

Bereits in der makroökonomische Analyse der Zinsstrukturkurve wurde versucht, die Verbindung zwischen der Zinsstrukturkurve und den makroökonomischen Größen zu schaffen. Solche Modelle beschäftigen sich jedoch mit dem Fall einer geschlossenen Wirtschaft, wo Zinssätze als eine inländische Angelegenheit betrachtet und ohne Anbindung an die Außenwelt modelliert werden. In meiner Arbeit schließe ich diese Lücke, indem ich die makro-ökonomische Betrachtung der Zinsstrukturkurve (also die Anknöpfung and die makrowirtschaftlichen Variablen) mit den Modellieransätzen der empirischen Literatur über internationale Konjunkturzyklen vereine. Ich schätze die inländische Zinsstrukturkurve unter Annahme wirtschaftlicher Einflüssen von außen, indem ich die makroökonomischen Faktoren als eine kointegrierte Vektorautoregression darstelle, eingebettet in einen affinen No-Arbitrage Ansatz zur Bewertung der Zinssätze und verzinslichen Anleihen. Kointegrierte Fehlerkorrekturvektorautoregressionen erlauben es von ihrem Aufbau her, kurz- und langfristige Zusammenhänge zwischen makroökonomischen und Finanz-Variablen zu erkennen und zu modellieren. Des Weiteren ermöglichen sie, wirtschaftliche Überläufe (sog. "Spillovers") zwischen Märkten, Sektoren und Ländern zu messen. Affine No-Arbitrage Modelle bilden eine Grundlage zur Bewertung der Zinsstrukturkurve unter Annahme konsistenter Bewertung der Wertpapiere und Wechselwirkung wirtschaftlicher und finanzwirtschaftlicher Faktoren.

Die offene Wirtschaft wird in der kointegrierten Fehlerkorrekturvektorautoregression modelliert, die in- (endogene) und ausländische (exogene) Variables beinhaltet. In meinem Modell werden die wichtigsten wirtschaftlichen Größen zusammengefasst, und ihre Entwicklung in ihrer Abhängigkeit von aktuellen und verzögerten Werten der ausländischen makroökonomischen Aggregate bestimmt. Die Überläufe von der Außenwirtschaft werden auf eine Art und Weise modelliert, die es erlaubt, eine Trennung zwischen kurz- und langfristigen Effekten durchzuführen. Auf diesem Prozess der makroökonomischen Faktoren baut ein affines No-Arbitrage Modell der Zinssätze auf. Insgesamt gewährt diese Vorgehensweise eine gewisse Flexibilität, da sie das simultane Modellieren der Makrofaktoren und Zinsen nicht vorschreibt, gleichzeitig aber erlaubt sich die Rückkopplung zwischen den beiden.

Der Einfluss der Makrofaktoren wird dem Prinzip von No-Arbitrage untergeordnet. Zwecks eines sparsamen Umgangs mit den Freiheitsgraden gehe ich in meiner Arbeit von der Annahme aus, dass die Marktrisikopreisfaktoren nur von zeitgleichen Beobachtungen der Variablen abhängen. Sowohl in- als auch ausländische Faktoren werden bei der Bestimmung der Marktrisikopreise einbezogen.

Die Schätzung des Modells erfolgt in zwei Schritten. Erstens, die Schätzer des Modell für die makroökonomischen Faktoren werden aus dem VECX* ermittelt. Das bedeutet im Besonderen eine Kalkulation der länderspezifischen ausländischen Variablen, eine Auswahl der geeigneten zeitlichen Struktur des Modells, eine Identifikation der langfristigen Kointegrationsrelationen vorausgesetzt Existenz instabiler Variablen, sowie eine Maximamwahrscheinlichkeitsschätzung unter Überidentifikationsbedingungen. Im zweiten Schritt werden die Marktrisikoparameter durch einer Minimierung der Fehler-Quadratsumme geschätzt.

Desweiteren werden die Eigenschaften des Modells im Hinblick auf seine Fähigkeit getestet, um empirische Resultate aus der Literatur bezüglich der Hypothese rationaler Erwartungen und der Risikoaufschläge auf dem Terminmarkt nachvollziehen zu können. Zum einen schätze ich sog. Campbell-Shiller-Regressionen: eine Regression der Renditenänderung auf Renditenspread und eine weitere Regression der risikoadjustierten Renditenänderung auf den Renditenspread. Der Test bezüglich der Risikoaufschläge auf dem Terminmarkt wird wiederum durch die Tatsache begründet, dass dieselben Faktoren die Risikoprämien der Zinsstrukturkurve bestimmen, beeinflussen auch die Risikoprämien des Devisenmarktes. Um es zu untersuchen, schätze ich folgende Regressionen: eine Regression der Wechselkursentwicklung auf die Zinsdifferenz zwischen In- und Ausland, sowie eine Regression der Änderung im risikoadjustierten Wechselkurs auf die Zinsdifferenz. Außerdem prüfe ich die Dynamik des Modells, indem ich Analysen der Impulsantworten und der Varianz der Vorhersagefehler vornehme. Durch eine "out-of-sample" Untersuchung wird die Prognosegüte des Modells geschätzt.

Das in diesem Kapitel vorgeschlagene Modell erweitert den Wissensstand der heutigen Literatur über Zinsstrukturkurve, indem es die Dynamik der Zinsen hinsichtlich der Auswirkungen erforscht, die durch Offenheit der Märkte bedingt sind. Meine Analyse zieht ökonomisch relevante und statistisch signifikante Relationen zwischen makroökonomischen Variablen in Betracht und erkundet die Implikationen der externen Effekte auf die Makrofaktoren und die Zinssätze. In einer empirischen Anwendung auf der Basis Schweizer Daten weise ich auf, dass das Modell imstande ist, die Zinsstrukturkurve sehr gut nachzubilden, und bezüglich der Prognosegüte das Nelson-Siegel-Modell schlägt, das selbst durch seine exzellente Vorhersagekraft bekannt ist. Des Weiteren dokumentiere ich in meiner Arbeit empirisch, dass die externen makroökonomischen Faktoren sehr viele Informatione beinhalten, die die Dynamik der Zinsstrukturkurve erläutern lassen.

Außerdem komme ich zum Ergebnis, dass das Modell die Resultate reproduzieren kann, die durch die Hypothese rationaler Erwartungen bedingt sind. Die Untersuchung des Zusammenhangs zwischen Zins- und Währungsrisiken ergibt, dass das Modell imstande ist, empirische Ergebnisse aus früherer Literatur bezüglich der Risikoaufschläge auf dem Terminmarkt und der Zinsparität nachzubilden.

Das letzte Kapitel meiner Dissertation beschäftigt sich mit Modellierung der Dynamik der makroökonomischen Größen zwischen verschiedenen Ländern, d.h. mit dem eigentlichen Prozess, der die Dynamik der Makrofaktoren aus dem zweiten Kapitel bestimmt. In diesem Teil meiner Dissertation bearbeite ich die Fragestellung, ob die Länder oder Ländergruppen in wirtschaftlicher Hinsicht dazu tendieren zu entkoppeln oder ob sie aufgrund zunehmender Globalisierung konvergieren. In den letzten Dekaden wurde die ökonomische Entwicklung weltweit durch zwei Kräfte beeinflusst. Zum einen, wurde die Weltwirtschaft zunehmend komplexer und die Wirtschaftsprozesse begannen immer mehr ineinander zu greifen. Im Laufe zunehmender Globalisierung erwiesen sich Nationalgrenzen und regionale Differenzen für international agierende Konzerne als immer weniger relevant. Zum anderen rief der Prozess der steigenden ökonomischen Selbständigkeit neue Wirtschaftsmächte hervor; die aufstrebenden Wirtschaften gewannen an Bedeutung, sie erhöhten merklich ihren Anteil an weltweiter Produktion und Wachstum. Diese beiden Phänomene haben die Weltwirtschaft in einer entscheidenden Art und Weise geprägt.

Die jüngsten makroökonomischen Studien liefern keine eindeutige Erklärung der Wirkungseffekte von engeren Handels- und Finanzbeziehungen zwischen den Ländern. Sie präsentieren außerdem widersprüchliche Aussagen hinsichtlich der Entwicklung und zeitgleichen Bewegung der makroökonomischen Hauptvariablen. So wird beispielweise einer engeren finanziellen Verflechtung oft ein höherer Grad am Gleichlauf der Konjunkturzyklen aufgrund Wohlstandseffekte zugeschrieben. Gleichzeitig jedoch wurde herausgefunden, dass Finanzbeziehungen zu fallenden Korrelationen der Produktion führen können, da sie Spezialisierung und Verteilung des Kapitals gemäß Wettbewerbsvorteile zwischen den Ländern unterstützen. Die Studie von Kose (2008), die ein Bayes'sches dynamisches Modell mit latenten Faktoren verwendet, fand heraus, dass Konjunkturzyklen innerhalb der Industrienationen und der aufstrebenden Länder sich ineinander annähern, wohingegen die Entwicklung zwischen den beiden Gruppen immer mehr auseinanderfallen.

Der innovative Beitrag meiner Arbeit besteht darin, nach Antwort für die Frage der wirtschaftlichen Konvergenz bzw. Divergenz in einem Globalen VektorAutoRegressiven Modell (GVAR) zu suchen, das eine hohe Anzahl der Länder in der Analyse zulässt ohne auf latente Faktoren zurückgreifen zu müssen. Im Gegensatz zu früheren Studien erschließt meine Arbeit sowohl makroökonomische als auch finanzielle Variablen und sie stütz sich auf Schätzungen wirtschaftlichen Abhängigkeit im Hinblick auf Handelswegen und Finanzbeziehungen. Zusätzlich dazu, setze ich mich mit der häufigen Kritik der GVAR Modelle auseinander, die sich auf Nutzung konstanter oder durchschnittlicher Gewichtungen bezieht. Ich baue zeitvariable Gewichte in das gesamte Modell ein, die mittels eines Sub-Modells geschätzt werden. Dieses Sub-Modell ermöglicht es, Projektionen der Gewichte herzustellen und eine Rückkopplung zwischen den makroökonomischen Variablen und den Gewichten zu errichten, sodass der dynamische Charakter dieser Zwischenbeziehung berücksichtigt wird. Alles in allem ist die Einführung zeitvariabler Gewichte mit einer zeitvariable Parametrisierung des GVARs Modells zu vergleichen.

In meiner Arbeit fasst das GVAR Modell 40 Länder, die individuell als Vektorautoregressionen (VAR) dargestellt werden. Der VAR Prozess jedes Landes umfasst inländische Variablen (endogene), länderspezifische ausländische (exogene) Variablen und eine globale gemeinsame Variable (Ölpreis), wobei die letzteren zwei Posten als "weakly exogenous" für die Binnenwirtschaft im statistischen Sinne angenommen werden. Diese Spezifikation ermöglicht es, die Relationen zwischen den Länder auf zweifache Art und Weise zu modellieren. Zum einen, es entstehen Beziehungen zwischen endogenen, exogenen und der globalen Variablen für ein Teilmodell des einzelnen Landes; zum anderen werden Interaktionen zwischen den Variablen aus verschiedenen Ländern zugelassen, deren Ausmaß in der Kovarianzmatrix erfasst wird.

Die Schätzung des Modells erfolgt durch Berechnung der Gewichtungen aus empirischen Daten, die das Ausmaß des Zusammenhangs zwischen den Ländern erfassen, und durch eine separate Schätzung der VAR der einzelnen Länder. Diese Prozedur kann angewandt werden, wenn das globale Modell stabil ist, die Gewichte relativ klein sind und landübergreifende Kovarianz der Schocks gering bleibt. Generell erfordert die Schätzung des Models eine Konstruktion der länderspezifischen exogenen Variablen mithilfe der zuvor berechneten Gewichte und eine Identifikation der Kointegrationsrelationen, die die gemeinsame Bewegung der makroökonomischen Größen im Modell definieren.

Die Spezifikation der Kointegrationsverhältnisse in einem GVAR-System hat einen besonderen Einfluss auf die Stabilität des Systems und das Verhalten der Impulsantworten. Aus diesem Grunde leiste ich folgender Schätzungsstrategie Folge: ich ziehe verschiedene kleinere GVAR Systeme mit unterschiedlichen Datensätzen in Betracht und überprüfen systematisch die Anzahl der Kointegrationsrelationen. Aufgrund der Tatsache, dass etwa 8% der länderspezifischen exogenen Variablen sich in Tests als statistisch endogen erweisen, schätze ich auch Sub-Systeme ganz ohne länderspezifische exogene Variablen. Zusätzlich vergleiche ich die Ergebnisse der Johansen-Tests fur Kointegrationsrelationen mit ARDL-Regressionen für einzelne Variablen in jedem Land. Diese Regressionen sind so aufgebaut, dass sie über das Vorhandensein der zu vermutenden makroökonomischen Zusammenhängen zwischen den Variablen Aufschluss geben können, wie zum Beispiel Produktionslücke zwischen der Binnen- und Außenwirtschaft, ungedeckte Zinsparität, langfristige Zinsregel in der Geldpolitik, in- und ausländische Aktienrisikoprämien, langfristige Korrelationen in der Entwicklung der Aktienmärkte sowie ein Zusammenhang zwischen Kreditmenge und Produktion. Schließlich führe ich mehrere Monte Carlo Analysen aus, um die Besonderheiten in der Performance der Kointegrationstests zu überprüfen.

Um dynamische Eigenschaften des Modells zu untersuchen, nehme ich eine Analyse der Impulsantworten und der Varianz der Vorhersagefehler vor. Zusätzlich dazu simuliere ich im Modell kontrafaktische Situationen, bei denen ich den Einfluss von verschiedenen Gewichtungsschemata auf die Dynamik des GVAR Systems schätze. Zum einen, vergleiche ich Impulsantworten auf der Basis der gemischten Gewichtung (gemischt aus Handels- und Finanzgewichte) aus dem Anfang, Mitte und Ende der Stichprobe. Zum anderen, ziehe ich pure Handelsgewichte in Betracht, um die Auswirkungen der Finanzgewichte einzuschätzen. Deweiteren, erstelle ich angesichts der Bedeutung der Gewichte für GVAR ein Sub-Modell für Gewichte, das ich in das gesamte Modell integriere. Dieser Schritt ermöglicht eine genauere Erfassung der Dynamik der Gewichte und eröffnet die Möglichkeit einer Rückkopplung zwischen den makroökonomischen Variablen und den Gewichten.

In meiner Arbeit berichte über zwei Hauptergebnisse. Zum einen weisen die Resultate darauf hin, dass die Entwicklung in den Handels- und Finanzbeziehungen zwischen den Ländern die grenzüberschreitende Verbreitung der wirtschaftlichen Schocks erweitert und die Konjunkturzyklen in den Regionen, die am stärksten Integriert sind, vor allem infolge Preisschwankungen der Finanzmärkte, verstärkt. Impulsantworten in der reellen Wirtschaft scheinen dagegen die Hypothese der auseinander driftenden Ökonomien zu unterstützen, indem sie unterschiedliche Pfade der Reaktionen auf Schocks aufweisen. Zum anderen, besagt meine Untersuchung, dass finanzielle Verflechtungen die Dynamik multilateraler Beziehungen verändern, indem sie mehr Moderation aber auch Entkopplung zwischen den Länderregionen herbeirufen. Im Gegensatz zu der Konvergenzhypothese scheinen die wachsenden Handels- und Finanzbeziehungen teilweise auch länderspezifische Konjunkturzyklen zu verursachen.

Part II

Research Papers

Chapter 1

Unconventional Monetary Policy and Bank Supervision

1.1 Introduction

The recent financial crisis has exemplified that financial intermediaries do matter for the propagation of shocks to the real economy. Motivated by this fact, we construct a dynamic general equilibrium model (DSGE) that incorporates a two-sided interbank market. We use this framework to investigate the transmission mechanism of monetary policy in an economy with nominal rigidities that faces a period of low interest rates. Assuming that at times of very low interest rates the usual tool kit of central bankers looses its bite, we study the effects of unconventional monetary policy tools such as: liquidity injections (quantitative monetary easing), asset swaps (qualitative monetary easing)[1], direct lending to firms and imposing tax on money.

In this paper, we also turn our attention to the possibility of adjusting the supervisory environment of banks. In particular, we examine effects on the economy for the case when banks are not only constrained by a minimum capital adequacy ratio but also by a leverage ratio which caps their ability to expand lending. Furthermore, we introduce an insurance scheme for bank equity according to which central bank may support the banking sector with additional funds (equity) in times of financial distress.

Our paper, however, goes beyond being a comprehensive review of the new monetary policy tools. Having taken the banking regulation and the unconventional monetary policy under scrutiny, we formulate implications for exit strategies from the unconventional monetary policy measures. In particular, we study how the formation of agents' expectation about the monetary policy affects the effectiveness of the central bank's actions. Our main results point at a rather limited impact of the expectations assumption on the monetary policy. However, in the presence of a lower bound on the policy rate, which con-

[1] Quantitative easing is associated with creation of new money and expansion of banks' balance sheet whereas asset swaps of loans in exchange for government bonds alter the composition of banks' assets in the balance sheet but leave the balance sheet totals unchanged.

siderably disrupts positive effects of liquidity injections for the real economy, the role of expectations is becoming more important. Overall, our findings indicate that the optimal monetary policy should embrace qualitative monetary easing for price stability, liquidity injections when addressing GDP growth and capital support to enhance the stability of the financial system.

Most workhorse general equilibrium models used in academia and central banks do not explicitly combine relations between financial actors, credit markets and the rest of the economy. Furthermore, models which incorporate financial frictions, starting with Bernanke et al. (1999) and later followed by Iacoviello (2005), fail to properly account for the cause of the recent crisis because they concentrate on the agency problem between banks and firms and emphasize the role of firms' collateral value. However, since current economic turmoil has been magnified by a near collapse of many financial institutions, we decided to put a heterogeneous banking sector with financial frictions generated by endogenous default rates, in the spirit of Goodfriend and McCallum (2007), at the centre of our model. This step allows us to accentuate the role of uncertainty in the banking system and capture the destabilizing effects of evaporating liquidity in the interbank markets.

Recently, other papers have investigated monetary policy in models with banking sector. Gertler and Karadi (2009) and Gertler and Kiyotaki (2010) propose a micro-founded banking setup with an asymmetric information problem between banks and investors, with a possibility of liquidity shocks in the interbank (wholesale) market. They analyze only qualitative monetary policy actions in terms of direct credit market interventions by modeling a central bank that issues government bonds to households and then lends this capital to non-financial firms. Gertler and Karadi (2009) conclude that welfare accumulation can be significant if central banks' efficiency costs are low. Our approach differs from Gertler and Karadi (2009) and Gertler and Kiyotaki (2010) in that we allow for endogenously defined default rates and multiple monetary tools aimed at different agents in the economy. Moreover, we take the formation of expectations into account when analyzing the effects of monetary policy measures. This enables us to consider the issues of central bank's credibility and commitment to its actions.

Angeloni and Faia (2010) introduce banks that are subject to runs into their model and explore the interplay between conventional monetary policy and bank regulation. They find that anticyclical capital requirements for banks can mitigate the effects of adverse shocks on output and inflation and postulate that the optimal monetary policy should consist of mildly anticyclical capital requirements and the conventional monetary policy that "leans-against-the-wind". Their analysis, however, does not explore the implications of heterogeneity of the banking sector for the monetary policy and disregards the significance of balance sheet effects in the banking system (as pointed for instance by Adrian et al. (2010)) for the propagation of shocks across the economy.

Recent but quickly growing part of the DSGE literature focuses on the industrial structure of the banking sector, following the Klein and Monti tradition. de Walque et al. (2009) develop a model along the lines of Goodhart et al. (2005) and Goodhart et al. (2006)

with a heterogenous banking sector and endogenous default probabilities acting as financial accelerator that generates countercyclical risk premia. Though the authors allow for liquidity injections, neither changes in the supervisory framework nor other unconventional monetary policy instruments are the subject of their analysis. Moreover, de Walque et al. (2009) fail to account for possible interactions between the conventional and unconventional monetary policy as their model lacks a presence of nominal rigidities. Dib (2010) investigates how liquidity injections and/or asset swaps provided to lending banks affect the economy. His study identifies disturbances in the banking sector as a substantial source of macroeconomic fluctuations and economic turmoil. Gerali et al. (2010) find that an unexpected reduction in bank capital can have a significant impact on the real economy and in particular on investment. They show that shocks that originate in the banking sector explain a large fraction of the fall in output while macroeconomic shocks play a smaller role. Acharya and Naqvi (2010) argue that the central bank should adopt an anticyclical monetary policy that responds to changes in bank liquidity. Overall, from our perspective none of those papers integrates all the necessary ingredients for a joint analysis of the monetary policy and banking regulation of an economy constrained by very low interest rates: heterogenous banking system, financial frictions, nominal rigidities and a comprehensive set of the unconventional monetary policy instruments.

In this paper, we analyze various unconventional monetary policy actions and consider different regimes of the supervisory framework for banks. To that end, we follow calls for a new supervisory standard have been demanded and discussed by public, researchers and regulators in the aftermath of the crisis[2] by addressing two possible changes in the bank regulation. First, we complement the standard capital requirement for banks with an additional one based on a leverage ratio, which so far has not been subject of the Basel II Accord. Moreover, we consider a further modification of setting the minimum capital ratio for banks in relation to some indicators of the macroeconomic activity in order to mitigate procyclicality of the capital adequacy rules. Consequently, the central bank in our model makes use of both the leverage ratio as well as the capital ratio that is a function of the output gap. Second, we introduce an insurance scheme for banks, as proposed for instance by Kashyap et al. (2008), in which insurance payments provide banks with additional funds. This insurance kicks in after an occurrence of a systemic "event". We define this "event" as a substantial increase in the credit default rates of firms and banks.

In our model, the central bank may also set tax on deposits in order to overcome the lower bound on the policy rate. Taxation of money was advocated by Buiter et al. (1999) and Goodfriend (2000), amongst others. We consider this tax as an option of escaping liquidity trap, in which additional increases in money stock fail to reduce interest rates further.

The rest of this paper is organized as follows. The setup of the basic model is introduced in Section 2. In Section 3, our impulse response analysis indicates that the quantitative

[2] See among many others “Annual Jackson Hole Economic Policy Symposium” in the year 2008 “Maintaining Stability in a Changing Financial System” or BCBS (2009) and BCBS (2009), for instance.

monetary policy is most effective (GDP, consumption, output, bank profits, solvency of banks and firms increase) but its impact seems to be of short duration. On the other hand, effects of qualitative monetary easing tend to be more persistent but lead to lesser increases in consumption and output. Equity injections to lending banks improve the stability of the financial system by raising the solvency level of lending banks and firms. Money taxation seems to work similarly to an expansionary monetary policy.

In Section 4, we investigate the role of expectations formation for the unconventional monetary policy and different supervisory rules We find that regardless of the assumption about the expectations (perfect foresight or perfect surprise) all monetary policy actions are effective in that they reduce losses in GDP and consumption. However, quantitative monetary actions increase the volatility of GDP and inflation whereas qualitative easing slightly reduces the variability of inflation. In addition, though the existence of banking sector magnifies business cycles, the heterogeneity of the banking sector reduces the volatility in the economy and makes unconventional monetary policy actions more effective. Our main result suggests that the role of expectations is very limited. The impact of qualitative easing, capital injections, and output driven capital ratio stays roughly the same under both the assumption of perfect foresight and of an unexpected change of the monetary policy. On the other hand, quantitative easing to banks is more effective when it is unexpected whereas liquidity injections aimed at non-financial firms seem to work better under full commitment, however, the differences tend to be relatively small. The presence of the lower bound on the policy rate substantially diminished the positive effects of quantitative monetary actions.

In addition to this short welfare analysis, Section 4 discusses estimation of the model using US data and - in particular - the estimates of parameters in the Taylor-type monetary policy rule. The last section concludes.

1.2 The baseline model

Our framework is a DSGE model with nominal rigidities. The economy is inhabited by households, banks, non-financial firms and a central bank. Banking sector consists of deposit and lending banks which interact in an interbank market. Central bank conducts both conventional and unconventional monetary policy; as our model lacks any distinct fiscal and supervisory authorities, we assume that the central bank takes over those roles. In particular, it supervises banking sector through capital and leverage ratios and is able to impose taxes on agents in the economy.

Overall, the economy is subject to various perturbations: productivity, monetary policy, quantitative and qualitative monetary easing shocks to banks and firms as well as imposing tax on money.

1.2.1 Households

Households allocate their resources to consumption C_t and investments and choose their leisure time $(1 - N_t)$. They provide labor N_t against wage w_t, place deposits D_t^h against an interest rate r_t^l with deposit banks and do not borrow. Following de Walque et al. (2009) we impose a target in deposits $\bar{D}^h$ via a quadratic disutility term[3]. This means that households dislike deviations of their deposits from the long-run optimal level. The households maximization program is given by:

$$\max_{C_t, N_t, D_t^h} \sum_{s=0}^{\infty} \beta^s E_t \left\{ \log\left(C_{t+s}\right) + \bar{m} \log\left(1 - N_{t+s}\right) - \frac{\chi}{2} \left(\frac{D_t^h}{1 + r_{t+s}^l} - \frac{\bar{D}^h}{1 + \bar{r}^l} \right)^2 \right\} \tag{1.1}$$

under the budget constraint:

$$C_t + \frac{\left(1 - T_t\right) D_t^h}{1 + r_t^l} = w_t N_t + \frac{D_{t-1}^h}{\pi_t} + \Pi_t^f + \left(1 - v_b\right) \Pi_t^b + \left(1 - v_l\right) \Pi_t^l \tag{1.2}$$

where $\pi_t = P_t / P_{t-1}$ is inflation and Π_t^f, Π_t^b, Π_t^l are profits of firms, lending banks and deposit banks, respectively. Households fully own firms and they receive a share of banks profits in line with retained earnings ratios v_b and v_l.

Furthermore, households may be subject to tax T_t imposed on their deposits by the central bank. In steady state $T = 0$ so that it has no further implications for the optimal choice of households. However, when set above zero, tax on deposits is supposed to encourage additional consumption, especially when reduction of the policy rate is not feasible any more. This mechanism works in our model due to the fact that households have no other option of storing money but to place deposits with banks[4]. In effect, taxing deposits temporally lowers the zero nominal interest rate floor which can easily be reached in an environment of low interest rates[5].

First order conditions of the households optimization problem are presented in Appendix.

1.2.2 Non-financial firms

Entrepreneurs choose price $P\left(i\right)_t$, labor $N\left(i\right)_t$, capital $K\left(i\right)_t$, loans $L\left(i\right)_t^f$ to rebuild capital stock and repayment rate on past borrowings $\alpha\left(i\right)_t$ from the profit maximization. They

[3] This term is necessary for technical reasons. For $\chi = 0$, first order conditions in (A.2) and (A.9) give the steady state for r_t^l leaving D_t^h undetermined. χ is kept very low so that the dynamics of the model are not altered significantly by its use.

[4] In the real world central bank would have to take into account considerable administrative costs of such an action. Holding large amounts of money in cash instead of in deposits would increase expenses. In addition, making interest rates negative would create stress for lenders and people heavily depend on interest income.

[5] Since $T = 0$ at steady state, the Friedman rule (of nominal interest rate being equal zero) is satisfied when following condition between inflation and representative household's rate of time preference is fulfilled: $1 = \beta / \pi$.

face price adjustment costs á la Rotemberg which introduce a nominal rigidity into the model.

$$\max_{P(i)_t, K(i)_t, N(i)_t, L(i)_t^f, \alpha(i)_t} \sum_{s=0}^{\infty} E_t \bar{\beta}_{t+s} \Pi\left(i\right)_{t+s}^f \tag{1.3}$$

where the profit is given by:

$$\begin{aligned} \Pi\left(i\right)_t^f &= \frac{P\left(i\right)_t}{P_t} Y\left(i\right)_t - w_t N\left(i\right)_t - \frac{\alpha\left(i\right)_t L\left(i\right)_{t-1}^f}{\pi_t} - \frac{M\left(i\right)_{t-1}^f}{\pi_t} \\ &\quad - \frac{\gamma}{2}\left[\left(1-\alpha\left(i\right)_{t-1}\right)\left(\frac{L\left(i\right)_{t-2}^f}{\pi_{t-1}} + d_f\right)\right]^2 - \frac{\psi}{2}\left(\frac{P\left(i\right)_t}{P\left(i\right)_{t-1}} - \pi^*\right)^2 Y_t \end{aligned} \tag{1.4}$$

π^* is the economy-wide inflation rate and the parameter ψ measures the degree of price stickiness. The higher ψ, the more sluggish is the adjustment of nominal prices; $\psi = 0$ implies flexible prices. In addition, non-financial firms bear quadratic costs of default on their loans[6]. At times of financial distress, when bank lending is scarce or difficult to obtain, central bank may step in and provide firms with additional liquidity $M\left(i\right)_t^f$ in order to help them to build up capital needed for production.

The production sector comprises of a continuum of monopolistically competitive firms each facing a downward-sloping demand curve for its differentiated product

$$Y\left(i\right)_t = \left(\frac{P\left(i\right)_t}{P_t}\right)^{-\theta} Y_t \tag{1.5}$$

where $P\left(i\right)_t$ is the profit-maximizing price consistent with production level $Y\left(i\right)_t$. Parameter θ is the elasticity of substitution between two differentiated goods. Both the aggregate price level P_t and aggregate output Y_t are beyond control of the individual firm. The aggregates for the economy are written as

$$Y_t = K_t^{\eta}\left(\exp\left(A_t\right) N_t\right)^{1-\eta} \tag{1.6}$$

$$K_t = \left(1-\tau\right) K_{t-1} + \frac{L_t^f}{1+r_t^b} + \frac{M_t^f}{1+r_t} \tag{1.7}$$

$$A_t = \rho_a A_{t-1} + \varepsilon_t^A \tag{1.8}$$

[6] The expenses related to default consist of a variable part that relates to the notional of outstanding loans in the economy, $\left(1-\alpha\left(i\right)_{t-1}\right)\frac{L(i)_{t-2}^f}{\pi_{t-1}}$, and an additional fixed cost, $\left(1-\alpha\left(i\right)_{t-1}\right) d_f$. Linearity of cost would imply indeterminacy for (A.5); partition of cost is done in analogy to the setup of the maximization problem for lending banks, where this partitioning allows to reconcile (A.9), (A.12) and (A.14) when determining steady state values for r_t^b, r_t^l and i_t.

de Walque et al. (2009) solve this technicality by splitting the expenses related to default into non-pecuniary costs that affect utility and pecuniary costs that impact profits. However, as they acknowledge, this 'double cost' lacks pure microfoundations. In our opinion, segmentation of the pecuniary default costs into a fixed and variable portion is more appealing micro-economically.

where firms produce output according to a Cobb-Douglas function with A_t functioning as an aggregate productivity shock. Equation (1.7) describes the law of motion for capital which depreciates at rate τ. Firms can obtain loans from lending banks L_t^f at interest rate r_t^b or receive liquidity from the central bank M_t^f at times of financial distress. Since firms are fully owned by households, their discount factor is given by:

$$\bar{\beta}_{t+s} = \beta^s \frac{C_t}{C_{t+s}} \tag{1.9}$$

First order conditions are solved assuming a symmetric equilibrium and are presented in Appendix.

1.2.3 Banks

When modeling the banking sector we lean on de Walque et al. (2009) and Dib (2010) and introduce deposit banks and lending banks. Both types of banks are risk-averse.

Deposit banks

Deposit banks collect deposits from households D_t^l and provide lending banks with loans D_t^{bs} on the interbank market. They also allocate their resources to a market book $\bar{B}^l$, which is assumed to be exogenous and to yield a return $\bar{\rho}$. In addition, deposit banks derive utility from holding own funds F_t^l above the capital requirement k and the leverage limit h - both imposed by the central bank - but they face opportunity costs $r_t F_t^l$ of maintaining these funds. We define leverage ratio as an inverse of the leverage multiple which is a ratio of total assets to equity. Contrary to the capital ratio, leverage ratio does not involve any riskiness weights of the assets and it serves as a primal measure of the sheer size of the balance sheet. In our basic setup we first assume that the central bank does not care about leverage ratio ($b_{F^l} = 0$); then, in Section 4, we present simulation results for the case when leverage ratio does become an instrument of financial regulation.

The maximization program of the deposit banks is:

$$\max_{D_t^l, D_t^{bs}} \sum_{s=0}^{\infty} E_t \bar{\beta}_{t+s} \left\{ \begin{array}{c} \log\left(\Pi_{t+s}^l\right) + d_{F^l}\left[F_{t+s}^l - k\left(w^l\left(D_{t+s}^{bs} - x_{t+s}^l\right) + \bar{w}\bar{B}^l\right)\right] \\ +b_{F^l}\left[F_{t+s}^l - h\left(D_{t+s}^{bs} + \bar{B}^l\right)\right] \end{array} \right\} \tag{1.10}$$

under the constraints:

$$\begin{aligned} \Pi_t^l &= \frac{\delta_t D_{t-1}^{bs}}{\pi_t} - \frac{D_t^{bs}}{1+r_t^i} + \frac{D_t^l}{1+r_t^l} - \frac{D_{t-1}^l}{\pi_t} + \zeta_l\left(1-\delta_{t-1}\right)\frac{D_{t-2}^{bs}}{\pi_{t-1}} + \frac{\bar{\rho}\bar{B}^l}{\pi_t} \\ &+ x_t^l - \frac{x_t^l}{1+r_t} + \frac{M_t^l}{1+r_t} - \frac{M_{t-1}^l}{\pi_t} - r_t F_t^l \end{aligned} \tag{1.11}$$

$$F_t^l = (1 - \xi_l + \varpi_l) \frac{F_{t-1}^l}{\pi_t} + v_l \Pi_t^l \tag{1.12}$$

Loans on the interbank market are prone to lending banks' default rate $(1 - \delta_t)$. Deposit banks' own funds increase by a share of profits that are not redistributed to households $v_l \Pi_t^l$; a small proportion of funds ξ_l is put into an insurance scheme run by the central bank. A fraction ζ_l of the lending banks' defaulted amount is paid back from this insurance, decreasing the losses suffered from impaired loans on the interbank market. Another portion of the insurance payout, provided by the central bank, is aimed to increase equity of the deposit banks by ϖ_l. This insurance payout kicks in only if the solvency of the lending banks deteriorates notably.

Furthermore, deposit banks can exchange a portion of their lending for a risk-free asset x_t^l as a measure of so called qualitative easing policy conducted by the central bank. The quantitative policy actions, i.e. liquidity injections, operate through M_t^l. We assume that the portion of assets x_t^l under the swap agreement is impaired and would not pay any return otherwise.

First order conditions are presented in Appendix.

Lending banks

Equivalently to deposit banks, lending banks derive additional utility from holding extra funds F_t^b (above the levels implied by the capital and leverage ratios) at the opportunity cost of $r_t F_t^b$. The maximization program of lending banks is given by:

$$\max_{D_t^{bd}, L_t^b, \delta_t} \sum_{s=0}^{\infty} E_t \bar{\beta}_{t+s} \left\{ \begin{array}{c} \log\left(\Pi_{t+s}^b\right) + d_{F^b} \left[F_{t+s}^b - k\left(w^b \left(L_{t+s}^b - x_{t+s}^b \right) + \bar{w} \bar{B}^b \right) \right] \\ + b_{F^b} \left[F_{t+s}^b - h\left(L_{t+s}^b + \bar{B}^b \right) \right] \end{array} \right\} \tag{1.13}$$

under the constraints:

$$\begin{aligned} \Pi_t^b \;=\; & \frac{\alpha_t L_{t-1}^b}{\pi_t} - \frac{L_t^b}{1 + r_t^b} + \frac{D_t^{bd}}{1 + i_t} - \frac{\delta_t D_{t-1}^{bd}}{\pi_t} - \frac{\omega}{2} \left[(1 - \delta_{t-1}) \left(\frac{D_{t-2}^{bd}}{\pi_{t-1}} + d_\delta \right) \right]^2 \\ & + \zeta_b (1 - \alpha_{t-1}) \frac{L_{t-2}^b}{\pi_{t-1}} + \frac{\bar{\rho} \bar{B}^b}{\pi_t} + x_t^b - \frac{x_t^b}{1 + r_t} + \frac{M_t^b}{1 + r_t} - \frac{M_{t-1}^b}{\pi_t} - r_t F_t^b \end{aligned} \tag{1.14}$$

$$F_t^b = (1 - \xi_b + \varpi_b) \frac{F_{t-1}^b}{\pi_t} + v_b \Pi_t^b \tag{1.15}$$

Lending banks provide loans to the firms L_t^b, borrow from deposit banks D_t^{bd}, invest in an exogenous market book $\bar{B}^b$ at yield of $\bar{\rho}$ and choose their optimal repayment rate δ_t. In addition, lending banks can receive liquidity injections from the central bank M_t^b (quantitative easing) or swap a fraction of their loans against a risk-free asset x_t^b (qualitative easing). We assume that x_t^b is impaired in that it pays no return when retained in the loan portfolio. Lending banks face pecuniary costs of default represented by a quadratic cost function $\frac{\omega}{2}\left[\left(1-\delta_{t-1}\right)\left(\frac{D_{t-2}^{bd}}{\pi_{t-1}}+d_\delta\right)\right]^2$. Quadratic formulation prevents indeterminacy in the first order condition (A.14); d_δ stands for a fixed costs of default which are independent from the total amount of the defaulted interbank loans $\left(1-\delta_{t-1}\right)\frac{D_{t-2}^{bd}}{\pi_{t-1}}$.

Similarly to deposit banks lending banks increase own funds by a share of profits that are not redistributed to households $v_b\Pi_t^b$; a small proportion of funds ξ_b is put into an insurance scheme, which is motivated by the fact that lending banks face losses on their loans to firms in accordance with firms' defaults ratio $(1-\alpha_t)$. A fraction ζ_b of the firms' defaulted amount is reimbursed by the insurance. In case of substantially increasing default rate among firms, lending banks may be supported by the equity capital ϖ_b provided by the central bank.

First order conditions are presented in Appendix.

1.2.4 Central bank

The monetary authority conducts its policy according to a Taylor-type policy rule:

$$(1+r_t)=\left(1+\bar{r}\right)^{(1-\mu_r)}\left(1+r_{t-1}\right)^{\mu_r}\left(\frac{\pi_t}{\pi^*}\right)^{Q_p}\left(\frac{Y_t}{Y_{t-1}}\right)^{Q_y}\exp\left(\varepsilon_t^r\right) \tag{1.16}$$

At times of financial distress it can use unconventional instruments: liquidity injections $M_t^{(\cdot)}$ (quantitative easing) and/or qualitative monetary easing $x_t^{(\cdot)}$ aimed at supporting the both types of banks and firms. We model all unconventional monetary tools as $AR(1)$ processes:

$$x_t^l=\rho_x x_{t-1}^l+\varepsilon_t^{x^l} \tag{1.17}$$

$$x_t^b=\rho_x x_{t-1}^b+\varepsilon_t^{x^b} \tag{1.18}$$

$$M_t^l=\rho_M M_{t-1}^l+\varepsilon_t^{M^l} \tag{1.19}$$

$$M_t^b=\rho_M M_{t-1}^b+\varepsilon_t^{M^b} \tag{1.20}$$

$$M_t^f=\rho_M M_{t-1}^f+\varepsilon_t^{M^f} \tag{1.21}$$

It is assumed that the deposit, interbank and commercial loan markets clear in the long run. However, in the short run the central bank may inject liquidity such that:

$$M_t^l=D_t^l-D_t^h \tag{1.22}$$

$$M_t^b = D_t^{bs} - D_t^{bd} \tag{1.23}$$

$$M_t^f = L_t^f - L_t^b \tag{1.24}$$

In addition, the central bank may impose tax on deposit holdings in order to overcome the zero bound on the policy interest rate. We model this tax rate as an $AR(1)$ process with the steady state value $T = 0$:

$$T_t = \rho_T T_{t-1} + \varepsilon_t^T \tag{1.25}$$

By assumption, the central bank finances liquidity injections, capital injections to banks, asset swaps and payoffs from the insurance scheme by collecting contributions from banks and by raising the deposit tax. Therefore, any liquidity creation beyond the financed amount is equivalent to expansion of the monetary base in the economy and thus generates inflation.

1.3 Results

1.3.1 Calibration

In the calibration we push our model towards a steady state with very low interest rates (around 0.5%) and yields on the market book (1%) in order to simulate an environment of low asset returns.

Real sector

We normalize employment to 0.2 and use Cobb-Douglas production function with labor share = 2/3. We utilize the assumption that capital stock is 10 times higher than production and set depreciation rate at 3%. This implies an investment ratio to output of 0.3 and allows us to avoid a negative search cost γ on the defaulted amount. ρ_a, the autoregression coefficient for the technology equation (1.8), is equal 0.95 which is a standard in the RBC literature.

We set the value for the default rate of firms equal 5% (an therefore $\alpha_t = 0.95$ in steady state) which is inferred from the US courts and the Bureau of Labor Statistics quarterly pre-crisis data on business bankruptcies. The data are based on the number of non-financial corporations that go bankrupt. This enables us to deduct values for γ (firms default cost parameter) and $\bar{m}$ (households leisure utility parameter). Both firms fixed default cost parameter and the smoothing parameter for deposits are set close to 0 ($\chi = 0.01, d_f = 0.001$), in order to eschew any dynamic effects (positive χ enforces finding a steady state value for D_t^h). We also introduce a penalty parameter for setting prices above the economy-wide level of 50, which we obtain by comparing the elasticity of inflation to the real marginal cost in our model with the slope coefficient of the log-linear Phillips curve using a Calvo approach. Expressed as $\frac{(1-\delta)(1-\beta\delta)}{\delta}$, where δ is the probability of not resetting the price, this slope coefficient is found in the literature to be around 0.75 (see discussion of the frequency of price adjustment in Faia and Monacelli (2007), for instance).

Banking sector

In order to simulate the environment of low interest rates we set the deposit rate at $\bar{r}^l = 0.35\%$ and assume that the market book offers a mere $\rho = 1\%$, which lies below the average quarterly return of the Dow Jones Industrial Average Index from 1980Q1 to 2010Q3 (1.96%). However, this assumption may actually be somehow questionable due to possible assets bubbles when interest rates, i.e. borrowing costs are extremely low.

We set lending banks default rate $\delta = 0.98$ which is derived from the pre-crisis data provided by the Federal Deposit Insurance Corporation. These data encompasses the number of bank failures. Furthermore, when calibrating the model we impose D^l/L^b to be around 2, $D^{bd}/L^b = D^{bs}/L^b$around 0.5, which is in line with pre-crisis statistics of the Federal Reserve System. The market book for each bank equals firm loans: $\bar{B}^b = \bar{B}^l = L^b$.

The weights of bank assets are aligned to the Basel agreement: $w^b = 0.8$ and $w^l = 0.05$. Capital ratio is set at $k = 8\%$ and leverage ratio at $h = 4\%$. Banks are supposed to allocate half of their profits to own funds ($v_b = v_l = 0.5$) and the remaining 50% are distributed to the households. The insurance scheme is assumed to enable banks to recover 80% of bad loans; in exchange, banks must pay premia of around $6 - 7\%$ of their funds ($\xi_b = 0.06$ and $\xi_l = 0.07$, due to differences in default rates for firms and lending banks) in order to benefit from this provision. The parameter of fixed default costs for lending banks d_δ is equal to 0.001.

Other parameters - default cost parameter ω and own funds utility parameters for both bank types, d_{F^b} , d_{F^l} , b_{F^b} and b_{F^l} - are inferred from the restrictions mentioned above.

Central bank

Taylor-type monetary policy rule contains parameters that are set according to specifications used in the literature and satisfy the Taylor rule principle ($\mu_r = 0.7$, $Q_p = 1.2$, $Q_y = 0.05$). Regression parameters for all unconventional monetary tools ($\rho_{(\cdot)}$) are set to 0.85.

1.3.2 Impulse responses

In this section we examine dynamic properties of our model by means of impulse response analysis. We investigate how shocks propagate through the system and affect the key macroeconomic variables. Our analysis starts with a short review of impulse responses to innovations in technology and monetary policy and then it passes on to inspection of shocks induced by unconventional monetary policy actions.

Standard analysis: technology and monetary policy

Figure A.1 in Appendix shows that a positive technology shock has positive effects on consumption, capital, output and GDP. In the short run all interest rates and inflation increase, but after about 10 periods they all fall below their initial steady state levels. Interbank, deposit and firms' lending rates react in a less pronounced way than the policy rate due to the adjustment costs of changing those rates.

Following the positive technology shock, demand for capital increases and is matched by a rising supply of loans to the firms. On the impact of the shock, profits of banks grow; however, firms' profits initially decline before returning to their pre-shock steady state level. This is due to rising capital costs caused by more expensive loans which also drives up the marginal cost. On the one hand, increase in the borrowing rate for capital reduces firms' profits. On the other hand, firms are subject to constraints set by price adjustment cost when trying to pass on the loan burden to consumers. Finally, positive technology shock leads to falling default rates for firms and lending banks; interest rates and inflation decrease in the long-run as a result of higher productivity and output.

When compared to Dib (2010), we observe responses to the technology shock in our model to be generally in line with his results. Notable exceptions are inflation and the policy rate where slightly different patterns of reaction can be observed. Dib (2010) finds that both fall immediately after the shock occurs and return gradually to their initial steady state levels thereafter. Yet, it seems to be reasonable that after a positive technology shock interest rates should increase. Two arguments speak in favor for this notion. First, central bank would increase its policy rate to close the output gap; second, higher demand for firm loans leads to an increase in interbank borrowing and thus to a rising demand for deposits. Consequently, the interest rates for these aggregates should increase.

As shown in Figure A.2 in Appendix, an expansionary monetary policy shock produces persistent moves in inflation and interest rates (except for the policy rate itself whose shock we model as an AR(1) process). After the monetary policy shock, consumption and capital increase; output stays almost unchanged; GDP grows, however, the effects on it seem to fade away relatively quickly. On the impact of the expansionary monetary policy shock banks' profits expand; in case of lending banks this is due to rising demand for commercial loans and improving solvency within firms. On the other hand, deposit banks' profits increase. This is due to the fact that the interest rate for their liabilities is decreasing stronger than the interest rate for their assets. Reaction of inflation is somehow puzzling as we would expect it to rise after a decrease in the policy rate. This is presumably attributable to the model setup in which production sector simultaneously marks up its production. Falling interest rates throughout the economy contribute to the reduction in marginal cost for firms, i.e. reduction in capital costs weights out rising labor cost. However, firms' profits tend to decrease temporarily on the impact of the monetary policy shock as initially the build-up in capital is not matched by an increase in output.

Dib (2010)'s analysis points to decreasing industrial loans and a short-run increase in the firms' borrowing rate after the expansionary monetary policy rate shock hits the economy. In our model, however, this shock leads to a fall in the borrowing rate along with an increased demand for firms' loans. We interpret our result as more intuitive since it reconfirms the expectation of falling interest rates throughout the whole economy after a cut in the policy rate.

Unconventional monetary policy

Quantitative monetary easing to banks and firms Figure 1.1 displays impulse responses after a liquidity injection to lending banks. This shock tends to have only temporary effects on economic aggregates. It decreases the risk-free rate, inflation, firms' borrowing rate, deposit rate and the interbank interest rate. Figure 1.1 shows that following a liquidity shock, output and GDP rise, yet their reaction - like for most of the variables - is not persistent. This effect is due to the persistence of liquidity itself as it is an AR(1) process with lag parameter ρ_{M^b}. Since we assume that in the steady state the interbank market clears, liquidity injections are equal to zero in the long run. Imbalances in the interbank market after the liquidity shock are then quickly forced to equilibrium by the movement in the interbank interest rate and an adjustment in default rate of lending banks. Liquidity injection to lending banks seems to crowd out interbank loans and to improve lending bank profits as they choose to default on a portion of their interbank borrowing given cheaper refinancing from the central bank. Deposit bank profits improve as well due to falling deposit rates.

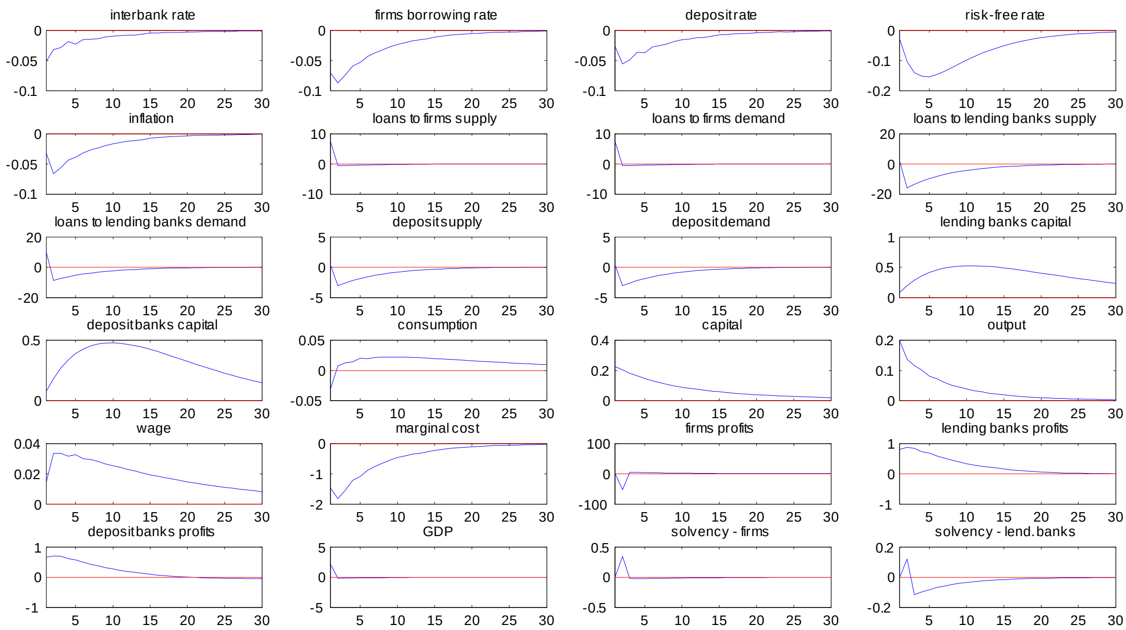

Figure 1.1: Responses to positive quantitative monetary easing shock to lending banks.

Our results generally reconfirm the findings of Dib (2010). Output, consumption, inflation, policy rate and other aggregates show the same pattern of behavior after the shock, however, they differ in persistence.

Liquidity injections to deposit banks serve as an instrument of supporting interbank market by strengthening the liquidity position of deposit banks (for instance, in case of significant deposit withdrawals). As shown in Figure A.3 in Appendix such liquidity injections to deposit banks generate responses that are quite similar to those following a quantitative monetary easing shock to lending banks. Yet its impact on GDP, consumption and in part on output tends to be of limited duration.

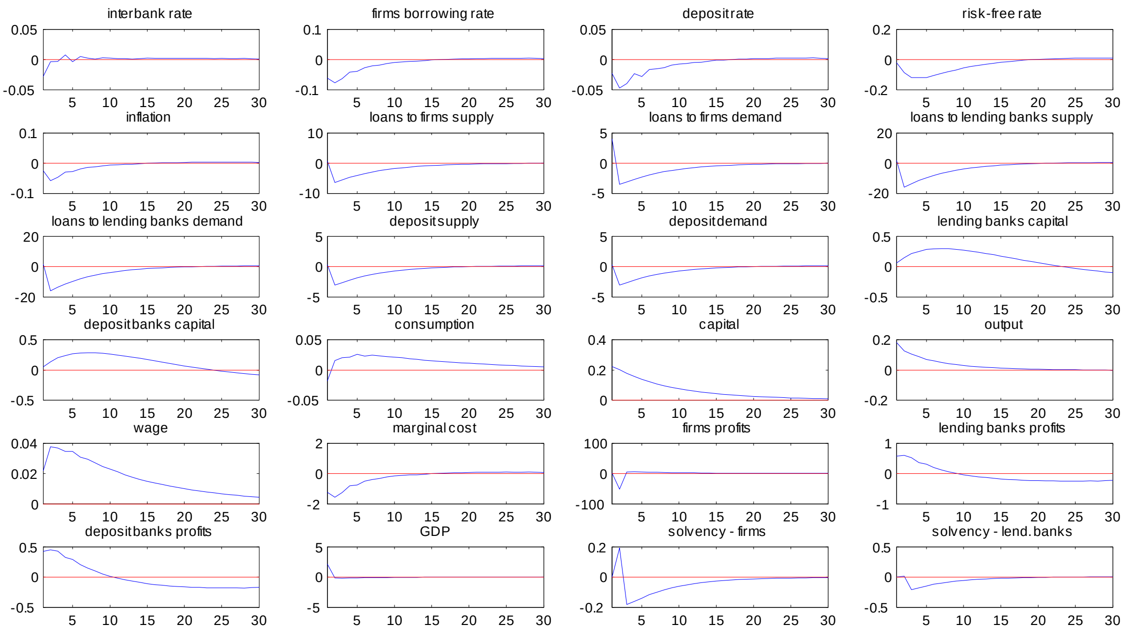

Figure 1.2: Responses to positive quantitative monetary easing shock to firms.

Notable is also a non-negative effect, as opposed to quantitative easing to lending banks, on lending bank default rate. In addition, even though M_t^l is injected at $r_t > r_t^l$ and thus above the initial refinancing cost, deposit bank profits rise and so does their capital, which by definition is partly cumulated from retained earnings. Lowering the price of this liquidity injection even further would, of course, have a positive influence on deposit bank profits, leaving its impact on other aggregates unchanged.

As illustrated in Figure 1.2, liquidity supply directed at firms improves output but has only a limited impact on GDP and consumption. When the central bank lends directly to firms, this action tends to crowd out bank loans to firms and to decrease lending on the interbank market. Motivated by cheaper financing, firms decide to default on some of its bank loans which in turn forces some of the lending banks to dishonor their debt. Altogether, impact to GDP is almost nil; only capital K_t and lending banks capital F_t^b

increase but all other components fall.

Qualitative monetary easing to banks Responses to a qualitative easing shock to banks are presented in Figures 1.3 and A.4 in Appendix. Contrary to quantitative easing, responses are mostly persistent. As a result of qualitative easing shock, policy rate and all other interest rates decrease, and inflation follows the same pattern of behavior.

The persistence of responses to the positive qualitative monetary easing shock in inflation, policy rate and the deposit rate does not stand in line with Dib (2010). This is probably due, to the way how qualitative (and quantitative) monetary actions enter into his model: it happens through a Leontief loan production function, where lending banks either use interbank borrowing plus liquidity injections or bank capital plus liquidity received from asset swaps. While in our paper after a qualitative shock interest rates fall, loan supply increases, marginal cost decreases and thereby reduces inflationary pressure, Dib's findings show almost no increase in loan supply accompanied by rising interest rates and an increase in inflation.

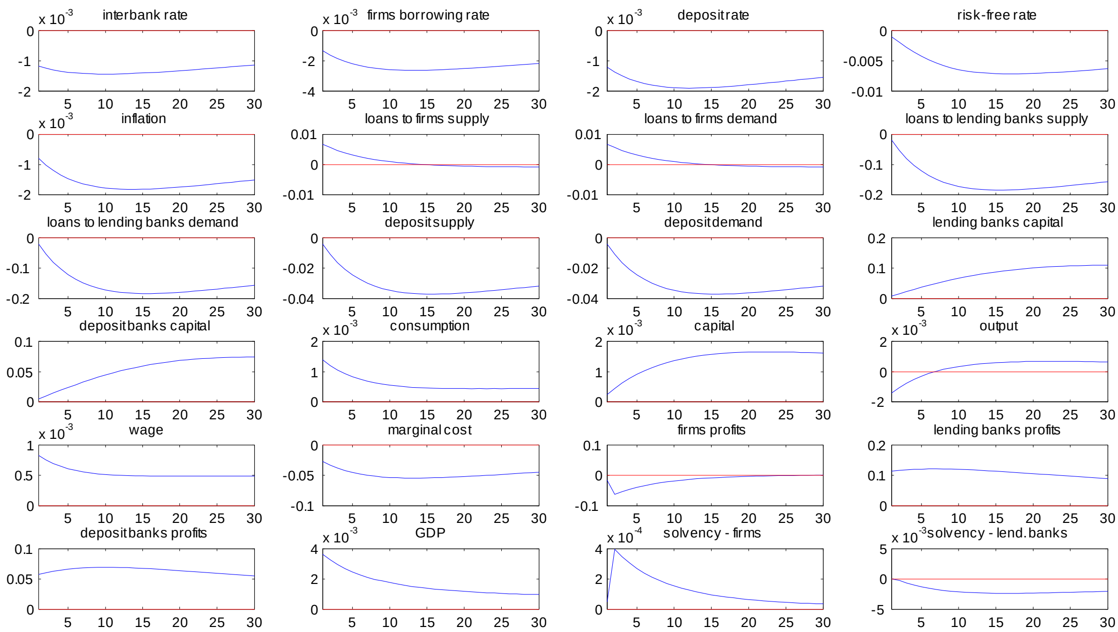

Figure 1.3: Responses to positive qualitative monetary easing shock to lending banks.

In our setup, the effects of assets swap tend to resemble the results for the traditional monetary policy shocks, with the same deflationary mechanism as before. As lending banks are relieved from impaired loans, they pick up on more lending causing the firms' borrowing rate to go down. As a result firms accumulate more capital, decide to default less on their lending, increase output (in the long run) and adjust their prices downwards in order to stimulate demand. Eventually, risk-free rate falls due to the fact that the

Taylor rule according to which monetary policy is conducted puts more weight on inflation changes than on the output fluctuations.

All variables bar loans to lending banks react similarly to the quantitative easing aimed at deposit banks as they did in case of this type of central bank action addressed at the lending banks (see Figure A.4 in Appendix). The possibility for deposit banks to swap their interbank loans has the same impact on the balance sheet of deposit bank as swaps of firm loans have on the balance sheet of lending banks: when the central bank absorbs impaired loans from banks' balance sheet (and thus improves deposit banks capital ratio), they instantly expand their lending on the interbank market at a lower price which, in turn, enhances solvency of lending banks.

When we compare the impulse responses for both types of banks, we observe that the solvency of firms, in both cases, increases remarkably in the short run and remains above its steady state in the medium to long run. However, the solvency of lending banks is decreasing when lending banks are allowed to swap their assets, but is strongly increasing in the short run and it remains above its steady state over the long horizon when deposit banks are the profiteers of the qualitative easing. This result indicates that qualitative monetary easing measures aimed at deposit banks can improve the stability of the financial system.

Capital insurance payments to banks As Figure 1.4 shows, insurance payout to lending banks' improves their solvency and has a persistent effect on the economy. It also increases loans to firms, raises their production capital marginally and that in turn leads to a raise in output. Since the Taylor rule is driven by output and inflation, the growth of output results in an increase of the policy rate. The subsequent rising in interest rates have an ambiguous impact on economy: they increase the marginal cost of capital for firms which are now trying to substitute capital with labor; in addition, higher interest rates make consumption less desirable and therefore push households towards more labor supply resulting in lower wage. As marginal cost increases, firms mark up the prices letting policy interest rate to climb up even further. As commercial loan costs pick up firms choose to default on some of their debt. Deposit and lending banks profits fall since in steady state their liabilities (deposits and interbank loans) outweigh their assets (interbank loans and loans to firms) in absolute terms, which leads to losses in case of rising interest rates.

We observe in Figure A.5 in Appendix that a similar mechanism is at work in case of an increase in deposit banks' equity. Generally, the responses tend towards rising interest rates, inflation and marginal cost of production whereas consumption, wage and production capital tend to fall. However, after an initial pick-up in credit supply to the economy, loans tend to fall in both real and financial sectors and as the level of interest rates raises, both firms and lending banks choose to default on more of their debt. The marginal increase in GDP seems to result from a small rise in the deposit banks' capital, as other components of GDP tend to fall.

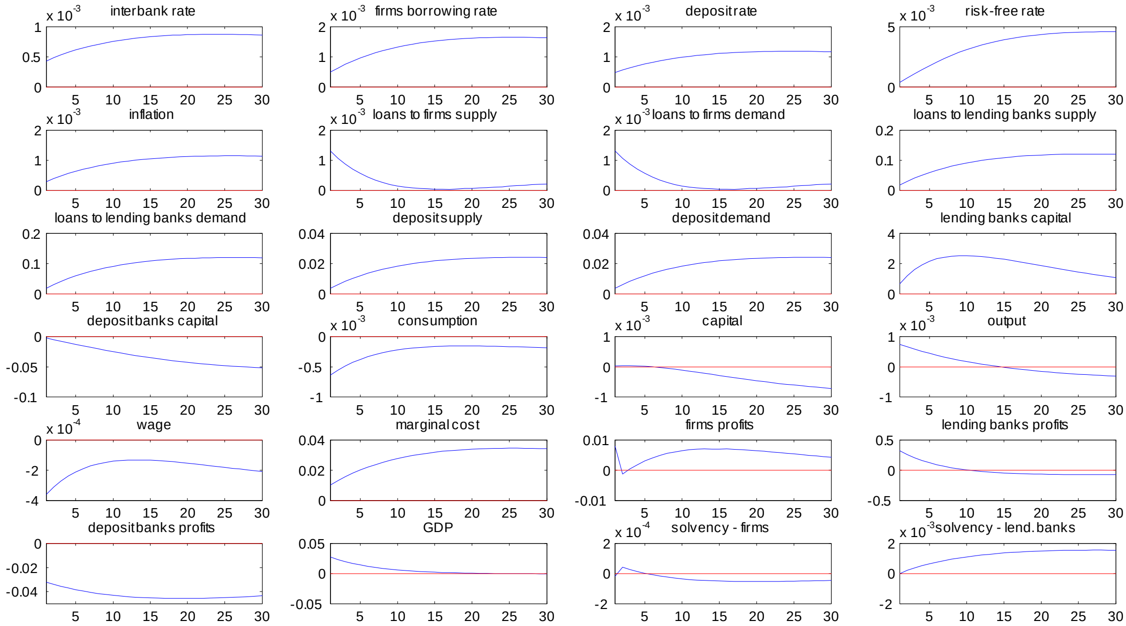

Figure 1.4: Responses to positive capital shock to lending banks.

Deposit tax Introducing a tax of 0.1% on deposits induces an expected fall in deposits but it otherwise has a strong positive impact on the economy. It raises GDP and output quite persistently, curbs interest rates and inflation and improves solvency rates of both firms and lending banks. It encourages more lending and strengthens banks' capital and profits.

Summing up, in our framework qualitative monetary easing impulses tend to produce more persistent changes in aggregates and their impact is similar to an expansionary monetary policy. A quantitative easing shock is likely to be more effective in the short run (in terms of changes in output and GDP) but does not seem to affect variables in the long run. It also turns out that a positive liquidity shock benefits both lending and deposit banks regardless of type of bank this action was initially aimed at. Qualitative and quantitative actions aimed solely at saving banks lead to higher solvency rates for lending banks suggesting better financial stability effects on the economy. However, liquidity injections tend to put more short-term strain on firms' profits than it is the case for qualitative easing or expansionary monetary policy shocks.

Capital injections to banks in form of insurance payments tend to raise output and GDP but they also contribute to an increase in interest rates and inflation. Their impact on default rates is mixed. Imposing a tax rate on deposits lower interest rates, boosts GDP, output and profits but decreases consumption.

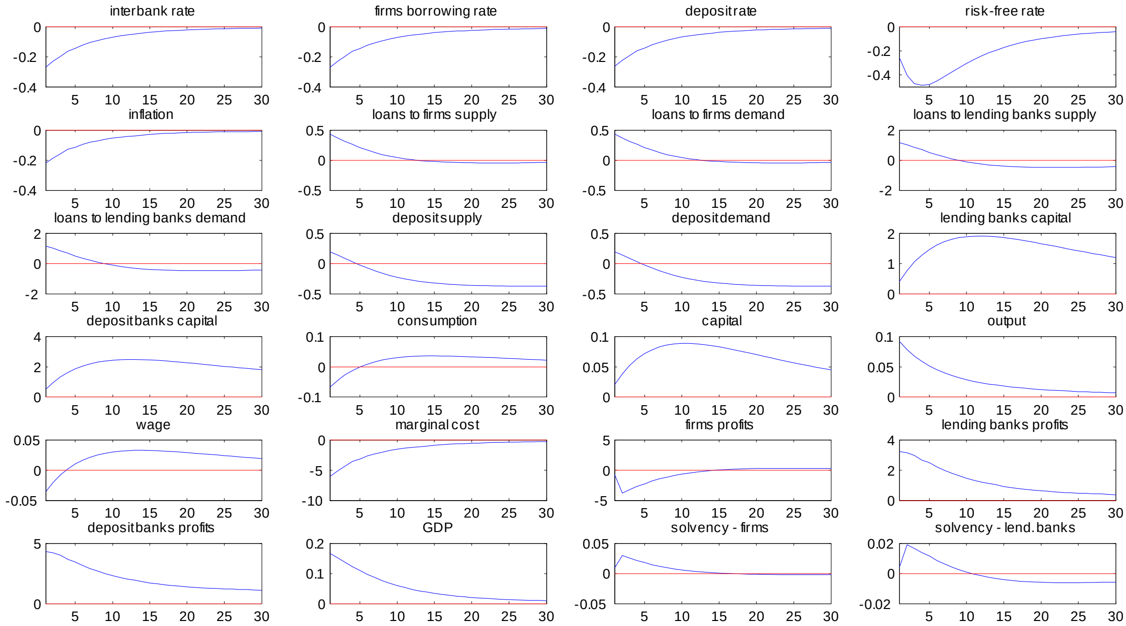

Figure 1.5: Responses to positive deposit tax shock.

1.4 Experiments

In this section we intend to simulate crisis conditions and then consider the role of central bank's instruments of unconventional monetary policy in moderating the crisis.

We conduct experiments with two versions of our model: the basic one, where default rates are endogenously chosen by firms and lending banks and another version in which default rates are exogenously given as $AR(1)$ processes:

$$\alpha_t = \rho_\alpha \alpha_{t-1} + \varepsilon_t^\alpha \tag{1.26}$$

$$\delta_t = \rho_\delta \delta_{t-1} + \varepsilon_t^\delta \tag{1.27}$$

The timeline looks as follows: in period one a shock that introduces a downturn of the economy occurs. In the first scenario it is a two standard deviations negative productivity shock; in the second version of the model with exogenous default rates we let the firms' and lending banks' solvency ratios fall by 2.5% and 5% respectively. This is supposed to replicate the origin of the ongoing financial crisis. In period two central bank steps in with its unconventional policy actions. We assume that in each case it commits 5% of GDP into its unconventional policy tools. We then evaluate the welfare effects simply by comparing present values of future consumption and GDP once central bank anti-crisis actions have been put in place. In particular, we take into account:

- liquidity injections to banks and firms,
- asset swaps with both types of banks,
- switching the regulatory regime to the environment where capital ratio k is a function of output gap such that:

$$(1 + k_t) = (1 + k) \left(\frac{Y_t}{Y_{t-1}} \right)^{Q_k} \exp\left(\varepsilon_t^k\right) \tag{1.28}$$

- direct capital injections to lending and deposit banks,
- switching the regulatory regime to the environment with leverage ratio h.

1.4.1 Perfect foresight of monetary policy

In the first case we run experiments in a deterministic context. We assume that agents have full foresight, they know when a shock is going to occur and how the central bank is going to react to it. Consequently, agents can specify in advance what actions they want to take in future given the shock and the central bank commitment to a particular monetary policy measure. In terms of computation, accounting for perfect foresight of monetary policy corresponds to running a single dynare file with economy entering a crisis in period one (either negative technology shock or a positive innovation in default rates of lending banks and firms) and a monetary policy action occurring at some time thereafter.

Table 1.1 presents results for our basic model with endogenous default rates. It reveals that all unconventional policy measures seem to be effective. With a notable exception of qualitative instruments, all policy actions mitigate adverse effects of a negative productivity shock on GDP and consumption[7]. Liquidity injections to firms seem to work best. The flipside of unconventional policy actions is the increased volatility of GDP and inflation, at least when quantitative monetary actions are considered. On the other hand, none of the unconventional policy measures tends to impact consumption volatility negatively.

Table A.1 in Appendix shows a summary for the version of our model with exogenous default rates. Here, we allow default rates for firms and lending banks to fall by 2.5 and 5 percent, respectively. Again, all central bank policy actions tend to reduce negative impact on GDP and consumption. Quantitative easing to banks contributes to the rising

[7] The impact of both the quantitative and qualitative monetary policy depends, of course, not only on the amount of money devoted to those measures but also on their price. In our model, we assume that the policy rate, r_t, defines the cost of liquidity injections and the return of asset swaps (both types of the unconventional monetary policy actions have different balance sheet effects, since liquidity injections affect liabilities whereas qualitative easing affects assets). If the central bank would use a higher markup, it would enhance the impact of the qualitative easing and dampen the effects of liquidity injections. Now, comparing how both instruments of the central bank perform in our experiments, we conclude that the impact of qualitative easing is more sensitive to conditions at which the central bank offers it rather than to the amount of money that is commited. It is apparent that for an economy facing a period of low interest rates liquidity injections are more desirable that asset swaps as long as the central bank deploys its policy instruments at market prices.

Table 1.1: GDP and consumption loss for a model with endogenous solvency rates

	basis scenario	$M_t^b+M_t^l$	M_t^f	$x_t^b+x_t^l$	$k\,(Y)$	$\varpi_b F_t^b+\varpi_l F_t^l$
	regulatory regime without leverage ratio ($b_{F^b}=b_{F^l}=0$)					
$\frac{\sum_{t=1}^{T}\beta^t(gdp_t-gdp)}{gdp}$	-17.23%	-8.80%	-8.24%	-17.10%	-16.98%	-16.51%
$\left(\frac{\sum_{t=1}^{T}(gdp_t-gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.556%	1.237%	1.200%	0.555%	0.549%	0.533%
$\frac{\sum_{t=1}^{T}\beta^t(C_t-C)}{C}$	-10.95%	-7.98%	-7.43%	-10.90%	-10.89%	-10.98%
$\left(\frac{\sum_{t=1}^{T}(C_t-C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.136%	0.141%	0.179%	0.179%	0.181%
$\left(\frac{\sum_{t=1}^{T}(\pi_t-\pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.042%	0.723%	1.041%	0.041%	0.058%	0.043%
	regulatory regime with leverage ratio ($b_{F^b}=b_{F^l}=10$)					
$\frac{\sum_{t=1}^{T}\beta^t(gdp_t-gdp)}{gdp}$	-17.21%	-10.02%	-5.91%	-16.64%	-16.97%	-16.53%
$\left(\frac{\sum_{t=1}^{T}(gdp_t-gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.554%	1.213%	1.171%	0.544%	0.547%	0.531%
$\frac{\sum_{t=1}^{T}\beta^t(C_t-C)}{C}$	-10.94%	-8.51%	-6.81%	-10.73%	-10.88%	-10.98%
$\left(\frac{\sum_{t=1}^{T}(C_t-C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.145%	0.152%	0.176%	0.179%	0.181%
$\left(\frac{\sum_{t=1}^{T}(\pi_t-\pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.031%	0.339%	0.816%	0.031%	0.041%	0.032%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a negative two standard deviations technology shock in a model with endogenous solvency rates. Consequent columns present results of quantitative easing to banks, quantitative easing to firms, qualitative easing to banks, regime switch to output driven capital ratio and capital injection to banks, respectively, amounting to 5% of GDP each. T = 30.

volatility of GDP and inflation whereas the same policy measure aimed at non-financial firms moderates both the downturn and the variability of GDP. In addition, making default rates exogenous seems to smooth GDP but it introduces slightly more variation into consumption and inflation.

In the regulatory regime with leverage ratio, results stay broadly in line with those from the scenarios without limits on bank leverage (both in case of endogenous as well as of exogenous default rates). It is worth noticing, that increased requirements on bank capital tend to make recessions less severe and the GDP less volatile.

When we look at inflation variability, liquidity injections tend to substantially increase the volatility of inflation whereas qualitative easing actions slightly reduce it. It seems that the central bank that is keen on using unconventional policy tools faces a difficult task of finding a proper mix of its policy instruments and it has to take into account the ability of those tools to reverse recession, their destabilizing impact on some of the macroeconomic aggregates and the horizon of the monetary policy. Results from Tables 1.1 and 1.2 suggest, that the central bank that puts more weight on targeting inflation should use more qualitative easing tools. On the other hand, central bank which primarily focuses on GDP should apply quantitative easing instruments. Therefore, the inflation targeting central bank would observe a higher output gap when trying to manage inflation in the short run whereas central bank that stabilizes GDP in the long run would produce an excessive inflation variability[8].

Table A.2 in Appendix reports results for a model with endogenous solvency rates and a homogenous banking sector. We find that shutting down one part of the banking sector makes recessions more severe in terms of GDP and consumption loss. Standard deviation of GDP and consumption rises whereas the variability of inflation decreases slightly. We conclude that having a heterogenous banking sector enhances economy's resilience against economic downturns and moderates the variation in the most macroeconomic aggregates. In addition, the heterogeneity of banks also improves the effects of monetary policy actions.

1.4.2 Unexpected change in monetary policy

Table 1.2: GDP and consumption loss for a model with endogenous solvency rates

	basis scenario	$M_t^b+M_t^l$	M_t^f	$x_t^b+x_t^l$	$\varpi_b F_t^b+\varpi_l F_t^l$
	regulatory regime without leverage ratio ($b_{F^b}=b_{F^l}=0$)				
$\frac{\sum_{t=1}^T \beta^t (gdp_t - gdp)}{gdp}$	-17.23%	-8.48%	-6.56%	-17.09%	-16.50%
$\left(\frac{\sum_{t=1}^T (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.556%	1.209%	1.156%	0.554%	0.533%
$\frac{\sum_{t=1}^T \beta^t (C_t - C)}{C}$	-10.95%	-7.95%	-7.00%	-10.90%	-10.98%
$\left(\frac{\sum_{t=1}^T (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.133%	0.142%	0.179%	0.181%
$\left(\frac{\sum_{t=1}^T (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.042%	0.580%	0.715%	0.040%	0.043%
	regulatory regime with leverage ratio ($b_{F^b}=b_{F^l}=10$)				
$\frac{\sum_{t=1}^T \beta^t (gdp_t - gdp)}{gdp}$	-17.20%	-10.35%	-5.38%	-16.61%	-16.53%
$\left(\frac{\sum_{t=1}^T (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.554%	1.205%	1.152%	0.542%	0.532%
$\frac{\sum_{t=1}^T \beta^t (C_t - C)}{C}$	-10.94%	-8.64%	-6.75%	-10.72%	-10.99%
$\left(\frac{\sum_{t=1}^T (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.145%	0.153%	0.176%	0.181%
$\left(\frac{\sum_{t=1}^T (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.031%	0.239%	0.850%	0.030%	0.032%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a negative two standard deviations technology shock; consequent columns present results of quantitative easing to banks, quantitative easing to firms, qualitative easing to banks and capital injection to banks, respectively, amounting to 5% of GDP each. T = 30. Model with endogenous solvency rates.

Now we turn our attention to a case in which monetary policy actions are not predetermined. We assume that the central bank did not commit to unconventional monetary policy actions so that they cannot be foreseen by the agents of the economy before they

[8] See discussion on the policy horizon in Smets (2003).

occur.

We simulate such a setup by letting the economy enter a recession at $t = 1$ in the first dynare file dynare file but not allowing for any unconventional monetary policy action to take place at that time. Then we start another dynare file that uses values of variables from the former dynare file as initial values. However, this new dynare file allows for some unconventional monetary policy action to enter the model from the very beginning of the simulation. Had no monetary policy action occurred in the second file, running such an experiment would produce exactly the same impulse responses as for the basic crisis scenarios used in the case of the perfect foresight. Therefore, we see in Table A.1 that the results for the basic scenario are the same as in the world with perfect monetary policy foresight. In addition, results for different monetary policy actions seem to resemble the outcome in the previous case of perfect foresight: we observe that most unconventional policy instruments tend to moderate recessions by limiting losses in GDP and consumption. Their impact on variability of the macroeconomic aggregates reveals similar patterns of increased volatility of GDP and inflation.

Table 1.3: GDP and consumption loss for a model with endogenous solvency rates with zero-bound on the policy rate

		expected change		unexpected change	
	basis scenario	$M_t^b+M_t^l$	M_t^f	$M_t^b+M_t^l$	M_t^f
	regulatory regime without leverage ratio ($b_{F^b} = b_{F^l} = 0$)				
$\frac{\sum_{t=1}^T \beta^t (gdp_t - gdp)}{gdp}$	-17.23%	-11.30%	-10.18%	-10.76%	-9.00%
$\left(\frac{\sum_{t=1}^T (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.556%	1.234%	1.195%	1.228%	1.176%
$\frac{\sum_{t=1}^T \beta^t (C_t - C)}{C}$	-10.95%	-8.93%	-8.49%	-8.81%	-8.21%
$\left(\frac{\sum_{t=1}^T (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.150%	0.162%	0.148%	0.167%
$\left(\frac{\sum_{t=1}^T (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.042%	0.575%	0.747%	0.758%	0.992%
	regulatory regime with leverage ratio ($b_{F^b} = b_{F^l} = 10$)				
$\frac{\sum_{t=1}^T \beta^t (gdp_t - gdp)}{gdp}$	-17.21%	-10.55%	-8.15%	-10.41%	-10.19%
$\left(\frac{\sum_{t=1}^T (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.554%	1.215%	1.174%	1.206%	0.952%
$\frac{\sum_{t=1}^T \beta^t (C_t - C)}{C}$	-10.94%	-8.69%	-7.94%	-8.67%	-8.58%
$\left(\frac{\sum_{t=1}^T (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.180%	0.148%	0.171%	0.146%	0.159%
$\left(\frac{\sum_{t=1}^T (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.031%	0.314%	0.971%	0.237%	0.651%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a negative two standard deviations technology shock; consequent columns present results of quantitative easing to banks and firms, under perfect foresight or unexpected change in the monetary policy, respectively, amounting to 5% of GDP each. T = 30. Model with endogenous solvency rates.

When comparing Table 1.2 with Table 1.1 we conclude that the effects of qualitative easing and capital injections are generally insensitive to the assumption on how agents form their expectations about future monetary policy actions. On the other hand, uncertainty about central bank's unconventional policy actions seems to matter more in case of liquidity injections. In particular, quantitative easing to non-financial firms is more effective when it is coming unexpectedly whereas liquidity injections aimed at banks seem to work the same way as under full commitment. However, this tendency for quantitative easing to firms is reversed when additional supervisory requirements regarding the leverage ratio are considered. Yet as observed in the case of perfect foresight, liquidity injections to banks and firms have a stronger effect on GDP and consumption when the leverage ratio of banks is not targeted.

Table A.3 in Appendix shows results of the unexpected unconventional policy actions in a model with exogenous solvency rates. Here, both direct lending to firms (best) and banks (second best) outperform other unconventional monetary policies in terms of GDP (7.52% and -1.48% respectively) and consumption smoothing (1.74% and -0.20% respectively). However, they also increase variation in consumption and inflation. Contrary to capital injections or qualitative monetary actions, quantitative policy instruments are more effective when unexpected by the agents of the economy; they tend to soften recessions but they exaggerate the variability of all variables at the same time.

As illustrated in Table 1.3, the presence of the lower bound on the policy rate considerably weakens the effects of liquidity injections for the economy. For a commitment of 5% of GDP to the quantitative easing to banks, 2,50% of the future GDP are foregone due to interest rates hitting the zero-bound. In case of liquidity injections to non-financial firms the recovery in GDP is by 1,94% percentage points lower as compared to the economy where the lower bound on interest rates is not binding. However, in an economy with very low interest rates, the effects of quantitative monetary policy may improve either due to increased capital requirements or as a result of unexpected policy actions. It should also be noted that though smoothing consumption, liquidity injections tend to substantially increase the variability of GDP and inflation.

What recommendations for the monetary policy can be derived from this analysis? This actually depends on the objective of the central bank. If price stability is on its watch list then the focus should be directed towards the qualitative easing tools. If the central bank wants to address GDP growth, it should make use of liquidity injections. In addition, our findings indicate that commitment to unconventional monetary policy actions plays a rather subordinated role. Unexpected policy changes improve the effectiveness of quantitative instruments to some extent, yet they leave the potential of other unconventional monetary tools almost unchanged. However, for the economy operating at very low interest rates, the role of agents' expectations gains on importance and additional capital requirements improve the effectiveness of the quantitative monetary easing.

1.4.3 Estimation of the policy rule

We take the baseline version of our model with endogenous solvency rates to data and estimate it employing Bayesian approach with Metropolis algorithm. In particular, we use three observable variables: industrial production (Y_t), policy rate (r_t) and inflation (π_t) and concentrate on estimating parameters of the policy rule given in Equation (1.16) as well as the estimation of shocks in our model. The sample contains US data running from 1997M7 to 2009M12.

Draws from the posterior distribution of the parameters are obtained by a random walk version of the Metropolis algorithm. We run 2 parallel chains each of length 10,000. The scale factor is set so that the acceptance rate lies between 20 and 30 percent. We allow for eight shocks in our system: technology shock (ε_t^A), monetary policy shock (ε_t^r), deposit tax shock (ε_t^T), quantitative easing shock to saving banks ($\varepsilon_t^{M^l}$), quantitative easing shock to lending banks ($\varepsilon_t^{M^b}$), quantitative easing shock to non-financial firms ($\varepsilon_t^{M^f}$), qualitative easing shock to saving banks ($\varepsilon_t^{x^l}$) and qualitative easing shock to lending banks ($\varepsilon_t^{x^b}$). Figure A.5 depicts the respective distributions for the policy rule given in Equation (1.16) whereas Table A.7 in Appendix presents results for all parameters under this study.

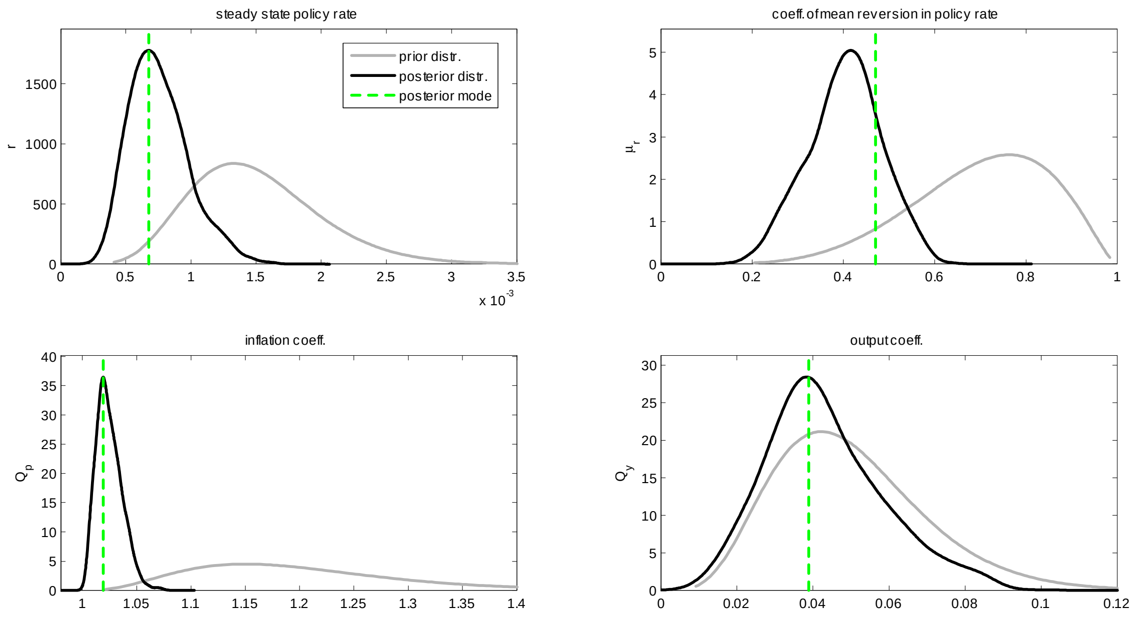

Figure 1.6: Prior and posterior distributions.

In particular, mean and standard deviation of the prior distributions together with the posterior mean, median and the respective 95 percent probability intervals are reported in Table A.6. In conformity with our observations from the impulse response analysis the outcome indicates that shocks in our model can generally be divided into two groups: more persistent innovations (technology shock and both qualitative easing shocks) and less persistent innovations (monetary policy shock, deposit tax shock, quantitative easing shocks). The 97 percent probability bands for the posterior distributions enclose most of the mean values we use for calibration of the model. However, concerning the parameters of the monetary policy equation we find that the mean of the policy rate ($\bar{r}$) lies considerably below the calibrated value. In addition, the coefficient of indexation to inflation (Q_p) is just above one and the parameter of mean-reversion in policy rate (μ_r) point at a higher degree of smoothing than initially assumed. Only in case of the output sensitivity (Q_y) does the policy rate seem to adjust to industrial production growth at the prespecified level of around 0.05.

1.5 Conclusion

The ongoing financial crisis revealed that standard DSGE models need to account for financial sectors of the economy. Recent research work[9] proposes models with heterogenous banking sector that are able to capture financial frictions and their transmission mechanism in the economy. We follow this approach and extend a relatively simple model of de Walque et al. (2009) by introducing a nominal dimension, several monetary shocks and changes in the rules of the financial supervision. In particular, this setup enables us to study impact of unconventional monetary policy actions at times of low interest rates when various capital adequacy requirements are in force.

We show that in this framework qualitative monetary easing impulses tend to produce more persistent changes in aggregates and their impact on GDP and consumption, though limited in magnitude, is similar to the expansionary monetary policy. Quantitative monetary easing shock, on the other hand, is more effective in the short run (in terms of changes in output and GDP) but does not seem to affect variables in the long run. When tax rates are imposed on cash holdings persistent changes in the economy are observed. Equity injections to banks achieve rather modest results. A direct capital payout to financial institutions diminishes consumption, raises inflationary pressure and results in small and temporary positive responses of output and GDP. Yet, equity injections to lending banks are able to substantially improve the solvency rates in the financial sector.

Our experiments in Section 4 also support the general result that the quantitative monetary policy actions are superior to other tools. In terms of consumption and GDP losses, direct credit to firms outperforms the unconventional actions aimed at banks. In addition, we conclude that in cases when capital ratio is tied to the output gap or when banks receive equity injections GDP fluctuations get smaller. In general, we observe that if financial institutions are supposed to meet additional capital adequacy requirements GDP volatility is smaller and recessions are less extreme.

Future work could consist of introducing other fiscal policy tools into the model. It would also be of interest to model richer financial markets with other financial interme-

[9] Dib (2010) and Gerali et al. (2010).

diaries, like brokers and so called shadow banks[10]. Recent research suggests that the analysis of their balance sheets could be used for prediction of economic activity and inflation dynamics[11].

[10] We refer to ABS issuers, finance companies and funding corporations as "shadow banks".

[11] See Adrian et al. (2010).

Chapter 2

Financial Integration and the Term Structure of Interest Rates

2.1 Introduction

The standard framework of modelling the yield structure uses a set of latent factors that are supposed to describe behavior of the term structure. Though found to explain term structure movements (Nelson and Siegel (1987) and Dai and Singleton (2000)) and documented to have good forecasting power (Duffee (2002) and Diebold and Li (2006)), such models pose difficulties to the interpretation of results because there is no clear understanding of what the factors actually mean in economic terms. Models with latent factors fail to relate the dynamics of the yield curve to the macroeconomic environment the term structure is a part of. This is in particular the case for open economies, which are influenced by both internal and external business cycles, and where interest rates may depend on expectations about macroeconomic variables from abroad. In this paper, I introduce a model that addresses those shortcomings and attains outstanding predictive ability for yields.

The seminal work of Ang and Piazzesi (2003), which augmented a traditional three-factor affine term structure model by incorporating macroeconomic variables within a no-arbitrage regime, inspired a whole stream of literature on models that link the mechanics of the entire yield curve to some key economic factors. Those models, however, are essentially concerned with the case of a closed economy where the term structure is treated as a domestic matter that is not directly related to financial considerations outside the country in question. My objective in this paper is to evaluate the yield curve of an economy influenced by spillovers from abroad by means of a structural cointegrated vector autoregressive model nested within a no-arbitrage affine term structure setup. Cointegrated VAR models are specifically designed to account for short-run and long-term interactions between macroeconomic and financial variables. This framework allows to study macroeconomic relationships and financial linkages between markets, sectors and countries. No-arbitrage affine term structure model provides a methodology of evaluation of the yield curve dynamics under assumptions of consistent bond pricing and interaction between key macro factors and interest rates.

Interest rates combine expectations of future rates, inflation and real activity as well as adjustment for risk. Therefore, understanding their dynamics is important both empirically and economically. As Ang et al. (2006) argue, the yields tell us a lot about future economic activity since they form a transmission channel between the monetary policy, real activity, inflation and asset prices. Monetary policy shocks impact mostly the short end of the yield curve[1] that is linked through expectations of the future evolution of the short-term interest rate and risk premia with yields for longer maturities, which in turn determine savings and investment decisions in the economy. Short-term interest rate influences movement in other asset prices through costs of borrowing and changes in wealth. In addition, yields affect exchange rates via interest rate parity conditions and thus constitute a channel of rapid demand and price adjustments in the international context, at least in case of open economies with flexible exchange rate regimes[2].

This paper relates to the econometric literature on cointegrated VAR systems and to the literature on term structure models. As with respect to the former, it builds on Pesaran and Shin (2002) and draws from Assenmacher-Wesche and Pesaran (2008), where the model was applied to analyse the degree of international interdependencies of the Swiss economy. It also relates to Pesaran et al. (2004), Dees et al. (2007) and Galesi and Sgherri (2009), were global VAR models were used to address the issue of synchronization of international business cycles and to analyse the transmission mechanism of real and financial shocks across borders. On the term structure side, this paper takes on ideas first introduced to the literature by Ang and Piazzesi (2003).

Recent macro-finance research provides a lot of insight into relationship between the real sector and yields. Hördahl et al. (2006) and Dewachter and Lyrio (2006) explore an approach of a joint model of the term structure and the macroeconomy and conclude that macro factors are useful for explaining and forecasting government bond yields. Ang et al. (2006) find that such models provide better out-of-sample forecasts for GDP growth. As Moench (2008) argues, exploiting larger macroeconomic information sets improves the model predicting power even further.

As shown in the literature, dynamics of the term structure are closely related to behavior of exchange rates. Backus et al. (2001), Dewachter and Maes (2001) and more

[1] For instance, Clarida et al. (2000) show that simple monetary policy rules explain well the dynamics of short-term interest rates.

[2] In practice, exchange rate movements often deviate significantly from what interest rate differentials would suggest. This empirical property - the forward premium anomaly - stands for mechanism in which currencies with high interest rates tend to appreciate against currencies with lower interest rates, rather than depreciate as unconvered interest rate parity (UIP) would suggest.

The reason for this fact may be that investors demand a risk premium, separate from the one that requires a higher interest rate, to compensate them for investing in a foreign currency. As this risk premium fluctuates, it may reverse the effects of the changes in interest rates. Another explanation may be related to inflation and purchasing power parity (PPP). It implies that real exchange rates should stay quite constant, while allowing nominal rates to vary. Then nominal interest rates should be higher in countries with higher inflation rates. PPP seems to hold over very long term and to support UIP; in the short run, however, currencies fluctuate and depart from the implied long-term equilibrium.

recently Diez de los Rios (2009), for instance, examine the forward premium anomaly and exchange rate forecasts in the context of term structure models. However, these papers use primarily latent factors in two-country models and thus leave unanswered the question of the impact of macroeconomic fundamentals in a multilateral setup.

This paper extends the existing research program by evaluating the relationship between macroeconomic aggregates and interest rates for an open economy. It accounts for economically relevant and statistically significant co-relations between variables and explores trade-based linkage between countries and its impact on key macro-factors and the term structure. Contrary to recent study of Spencer and Liu (2010) who also call into question the standard closed economy macro-finance specification, the model in this paper does not use latent factors, it is flexible at the specification of the country-dimension and facilitates consistent modelling of stationary and non-stationary variables simultaneously. The framework I use is able to overcome the dimensionality problem often faced by global macroeconomic empirical models by modelling links between countries through foreign variables calculated as averages of macroeconomic aggregates of the partner economies. In contrast to latent factors, those foreign variables have a natural theoretical interpretation. Moreover, this specification allows a transparent long-run theoretical structure and permits testing and imposing, if necessary, short-run overidentifying theoretical restrictions. The model in this paper fits well the yield curve in-sample and shows a sound ability to forecast interest rates out-of-sample. In its basic setting it is capable, to a great extent, to outperform a generalized version of Nelson-Siegel model put forth by Diebold and Li (2006) which has been documented to be particularly useful for interest rate predictions. Moreover, by comparison to a case of closed economy it is shown that external macroeconomic variables contain a lot of information that helps to explain the dynamics of the domestic term structure.

Having produced an empirical model that successfully captures the importance of real and financial spillovers between economies for the term structure, the paper examines whether the model accounts for the expectations hypothesis. I follow the approach of Dai and Singleton (2002) for analysing regressions of the yield change on the yield spread as initially proposed in work of Campbell and Shiller (1991). The model is able to capture risk-premium adjusted yield changes by reproducing the coefficients implied by the expectations hypothesis. In addition, the framework presented in this paper is used to examine the relation between the term structure and exchange rates. I find that the model successfully replicates empirical findings and accounts for the forward premium anomaly characterized by regression from Fama (1984). Moreover, the model is able to reconcile the uncovered interest rate parity implications once the implied exchange rate risk premia are considered.

This paper is organized as follows. Section 2 describes the structure of the model and explains its parametrization and the estimation method. Section 3 reports results of the estimation, describes expectation hypothesis tests, discusses the relation between interest rates and exchange risk premia, and documents the dynamic properties of the model. Section 4 presents out-of-sample forecasting results and compares them with yield projections for a closed economy model. Last section concludes.

2.2 Methodology and data

The open economy is modelled in a VAR approach that follows Pesaran and Shin (2002) and Assenmacher-Wesche and Pesaran (2008). This model relates the core macroeconomic variables to current and lagged values of a number of key foreign country-specific variables. Spillovers from abroad to the open economy enter the regression in a way that allows to separate the relationships between variables into short-term and long-run relations.

On top of the VAR process that governs the dynamics of macroeconomic factors an affine no-arbitrage framework is used to examine behavior of the term structure. This setup does not require to model the dynamics of macro variables and yields jointly, nevetheless it does allow for feedback between them.

A standard small open economy model usually accounts for financial linkage between the basis economy and the rest of the world by means of conditions describing the connection between domestic and foreign interest rates and the domestic rate of the expected inflation. The model used in this paper goes beyond that setup in that it allows for interactions between real macroeconomic variables and considers both short- and long-term effects. It assumes a multi-country open economy framework that consists of countries which may differ in size but are otherwise isomorphic, i.e. have similar structure. Due to this assumption the exposition below is set to focus mainly on the "home" country. Such a specification does not require to explicitly specify whether the home country is a small open economy that participates in world markets without being able to alter world prices, interest rates or incomes through its policies. Yet, as the number of countries in the model N gets large, the conditions unter which the model is estimated provide a formal definition of a small open economy. In this regard, Switzerland - for which I estimate the model later on - can certainly be considered as a small open economy in the global context.

Following the discussions from Abel and Bernanke (2001), the theoretical constraints, as applicable to a small open economy, could then be considered when setting up the model and defining relationships between economic aggregates. In particular, one can expect that domestic and global currency demand and supply factors influence the exchange rate of a small open economy. A growth in foreign liquidity or income would raise demand for domestic goods and currency leading to a strengthening of the domestic currency in value. Higher real rates of return on domestic assets, e.g. interest rates, equity returns and property values, would also stimulate the demand for domestic currency as more investors would favor investing in the domestic market. Increases in domestic inflation rates and income, on the other hand, would cause the demand for foreign goods to raise and the purchasing power to fall. This, in turn, would result in a decline in the value of the domestic currency.

2.2.1 Structure of the model

Macroeconomic factors

The model for state variables comprises of a structural cointegrated vector autoregression (called $VECX^*$ henceforth) that embeds domestic (or endogenous) variables x_t and country-specific foreign variables x_t^* whereas the latter are assumed to be weakly exogenous to the open economy.

Weak exogeneity refers to foreign variables in the sense that they affect the domestic variables contemporaneously but they are not affected by disequilibria in the domestic economy. However, foreign variables could be affected by lagged changes of domestic and foreign variables. Technically speaking, in error correcting regressions of changes in foreign variables in the $VECX^*$ model none of the lagged error correction terms associated with the domestic economy should be statistically significant. Therefore - in the context of $VECX^*$ - weak exogeneity differs from the notion of "Granger (Non)Causality" which would imply that none of the domestic variables be allowed to enter the regression for the foreign variables. Granger and Lin (1995) refer to weakly exogenous $I(1)$ variables as "long-run" forcing[3].

After grouping both the domestic and the foreign-specific variables in one vector

$$z_t = \begin{pmatrix} x_t \\ x_t^* \end{pmatrix} \tag{2.1}$$

and assuming that $\{z_t\}_0^\infty$ is generated by a vector autoregression

$$\left(I - \sum_{i=1}^{p} \Phi_i L^i\right)(z_t - \mu - \gamma t) = u_t$$

where L stands for a lag operator, and defining matrices $\Pi = \left(\sum_{i=1}^{p} \Phi_i - I\right)$ and $\Gamma_i = -\sum_{k=i+1}^{p} \Phi_k$, the model can be rewritten in its error-correction form as

$$\Delta z_t = a_0 + a_1 t - \Pi z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + u_t \tag{2.2}$$

with

[3] A variable is said not to Granger-cause another variable if it does not contain information about the forecastability of that variable. This feature is neither necessary nor sufficient for weak exogeneity since it is a predictive feature which is not useful for parameter inference.

In fact, the definition of weak exogeneity, as initially introduced in Engle et al. (1983), aims at the efficiency of estimation. For instance, in bivariate context with the joint distribution depicted as the product of a marginal distribution and a conditional distribution:

$$f(x, y) = f(y|x)\, f(x) = f(x|y)\, f(y)$$

x is defined to be weakly exogenous for the purpose of estimating the parameters of interest if there is no loss of information when one ignores the details of the marginal distribution $f(x)$ when making inferences about the parameters of the conditional distribution $f(y|x)$.

$$
\begin{aligned}
a_0 &= -\Pi\mu + (\Gamma + \Pi)\gamma \\
a_1 &= -\Pi\gamma \\
\Gamma &= I - \sum_{i=1}^{p-1}\Gamma_i
\end{aligned}
\tag{2.3}
$$

In this specification, matrix Π contains long-run multipliers and the matrices $\{\Gamma_i\}_{i=1}^{p-1}$ include short-run parameters.

Partitioning of the error term u_t conformably with z_t as $u_t = (u'_{xt}, u'_{x^*t})'$ and its variance matrix as

$$
\Sigma = \begin{pmatrix} \Sigma_{xx} & \Sigma_{xx^*} \\ \Sigma_{x^*x} & \Sigma_{x^*x^*} \end{pmatrix} \tag{2.4}
$$

allows to express u_{xt} conditionally in terms of u_{x^*t} as

$$
u_{xt} = \Sigma_{xx^*}\Sigma_{x^*x^*}^{-1}u_{x^*t} + v_t \tag{2.5}
$$

where $v_t \sim iid\,(0, \Sigma_{vv})$, $\Sigma_{vv} = \Sigma_{xx} - \Sigma_{xx^*}\Sigma_{x^*x^*}^{-1}\Sigma_{x^*x}$, is uncorrelated with u_{x^*t} by construction.

Furthermore, substitution of (2.5) into (2.2) together with similar partitioning of the remaining parameters in (2.2), i.e. $a_0 = (a'_{x0}, a'_{x^*0})'$, $a_1 = (a'_{x1}, a'_{x^*1})'$, $\Pi = (\Pi'_x, \Pi'_{x^*})'$, $\Gamma_i = (\Gamma'_{xi}, \Gamma'_{x^*i})'$, $i = 1, ..., p-1$, and the assumption that x^*_t are weakly exogenous (thus $\Pi_{x^*x} = \mathbf{0}$) provide a possibility to subdivide the model into a conditional model for the endogenous variables x_t and a marginal model for the weakly exogenous variables x^*_t. The former is written as

$$
\Delta x_t = c_0 + c_1 t - \Pi_x z_{t-1} + \Lambda\Delta x^*_t + \sum_{i=1}^{p-1}\Psi_i\Delta z_{t-i} + v_t \tag{2.6}
$$

where $c_0 = a_{x0} - \Sigma_{xx^*}\Sigma_{x^*x^*}^{-1}a_{x^*0}$ and $c_1 = a_{x1} - \Sigma_{xx^*}\Sigma_{x^*x^*}^{-1}a_{x^*1}$ and the matrix Π reads as:

$$
\Pi = \begin{pmatrix} \Pi_x \\ \Pi_{x^*} \end{pmatrix} = \begin{pmatrix} \Pi_{xx} & \Pi_{xx^*} \\ \mathbf{0} & \mathbf{0} \end{pmatrix} \tag{2.7}
$$

The marginal model for the exogenous variables (assuming that x^*_t variables are $I\,(1)$ but not cointegrated (thus $\Pi_{x^*x^*} = \mathbf{0}$) so that a linear model in first differences is appropriate[4]) takes the following form:

[4] To test for cointegration among the exogenous variables I estimate a system with lag order of two, an unrestricted constant and a restricted trend and find no cointegration at the 10 percent level of significance.

$$\Delta x_t^* = a_{x^*0} + \sum_{i=1}^{p-1} \Gamma_{x^*i} \Delta z_{t-i} + u_{x^*t} \tag{2.8}$$

In order to eschew a possibility of having quadratic trend in the model due to variables in levels with unit root[5], a restriction is placed on linear trend such that

$$c_1 = \Pi_x \kappa \tag{2.9}$$

Then the error-correction equation of the conditional model for the endogenous variables in $VECX^*$ can be expressed as:

$$\Delta x_t = \widetilde{c}_0 - \Pi_x [z_{t-1} - \kappa(t-1)] + \Lambda \Delta x_t^* + \sum_{i=1}^{p-1} \Psi_i \Delta z_{t-i} + v_t \tag{2.10}$$

where

$$\widetilde{c}_0 = c_0 + \Pi_x \kappa \tag{2.11}$$

Matrix Π_x can be rewritten as

$$\Pi_x = \alpha_x \beta' \tag{2.12}$$

where α_x is a $k_x \times r$ loading matrix of rank r, β is a $(k_x + k_{x^*}) \times r$ matrix of cointegrating vectors of rank r. Π_x specifies the number of long-run relationships that exist among domestic variables x_t and country-specific foreign variables x_t^*. If no cointegrating relationships exist (2.10) collapses to a VAR regression in first differences.

The full-system $VECX^*$ arises from the conditional model for Δx_t that is augmented by the marginal model of Δx_t^*. This is written as

$$\Delta z_t = a_0 + a_1 t - \alpha \beta' z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + H \zeta_t \tag{2.13}$$

where β is defined by (2.12) and

[5] For instance, if we consider a version of the model of order 1:

$$(I - A_1 L)(z_t - \mu - \gamma t) = u_t$$

with $u_t \overset{iid}{\sim} (0, \Sigma_u)$ and $(I - A_1 L) = A(L)$, and re-write it to:

$$A(L) z_t = a_0 + a_1 t + u_t$$

where $a_0 = -\Pi\mu + A_1$ and $a_1 = -\Pi\gamma$, we can re-formulate it again to:

$$\Delta z_t = C(L)(a_0 + a_1 t + u_t) = b_0 + b_1 t + C(L) u_t$$

with $C(L)$ defined as $C(L) A(L) = (1 - L) I$.
Now, re-expressing last equation for Δz_t in levels we obtain:

$$z_t = z_0 + b_0 t + b_1 \sum_{s=1}^{t} s + \sum_{s=1}^{t} C(L) u_s = z_0 + b_0 t + b_1 \frac{t(t+1)}{2} + \sum_{s=1}^{t} C(L) u_s$$

$$\alpha = \begin{pmatrix} \alpha_x \\ 0 \end{pmatrix}, \; \Gamma_i = \begin{pmatrix} \Psi_i + \Lambda \Gamma_{x^*i} \\ \Gamma_{x^*i} \end{pmatrix}, \; a_0 = \begin{pmatrix} c_0 + \Lambda a_{x^*0} \\ a_{x^*0} \end{pmatrix}, \; a_1 = \begin{pmatrix} c_1 \\ 0 \end{pmatrix}, \tag{2.14}$$

$$\zeta_t = \begin{pmatrix} v_t \\ u_{x^*t} \end{pmatrix}, \; H = \begin{pmatrix} I_{k_x} & \Lambda \\ 0 & I_{k_{x^*}} \end{pmatrix}, \; Cov\left(\zeta_t\right) = \Sigma_{\zeta\zeta} = \begin{pmatrix} \Sigma_{vv} & 0 \\ 0 & \Sigma_{x^*x^*} \end{pmatrix} \tag{2.15}$$

Finally, Equation (2.13) without time trend can be rewritten as

$$z_t = \mu + \sum_{i=1}^{p} \Phi_i z_{t-i} + H\zeta_t \tag{2.16}$$

where $\mu = a_0$, $\Phi_1 = I_{(k_x+k_{x^*})} - \alpha\beta' + \Gamma_1$, $\Phi_i = \Gamma_i - \Gamma_{i-1}$, $i = 2, ..., p-1$, $\Phi_p = -\Gamma_{p-1}$. For lag order $p > 1$, equation (2.16) can be reformulated to $VAR\left(1\right)$ in companion form, i.e.:

$$\bar{z}_t = \bar{\mu} + \left\{\Phi_i\right\} \bar{z}_{t-1} + \bar{H}\bar{\zeta}_t \tag{2.17}$$

with $\left\{\Phi_i\right\}$ defined as:

$$\left\{\Phi_i\right\} = \begin{pmatrix} \Phi_1 & \Phi_2 & \Phi_3 & \dots & \Phi_p \\ \mathbf{1} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{1} & \mathbf{0} & \dots & \mathbf{0} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \mathbf{0} & \dots & \mathbf{0} & \mathbf{1} & \mathbf{0} \end{pmatrix} \tag{2.18}$$

Adding the term structure

Term structure model suggested in this paper is built upon the idea that domestic capital markets of an open economy are closely related to their external counterparts. If this is true, domestic term structure of interest rates cannot be independent of the external world macroeconomic factors or foreign interest rates. However, at this point I propose a modelling choice of estimating domestic term structure given internal and external processes of macroeconomic factors - as opposed to an alternative approach to study dynamics of domestic and foreign yields jointly under assumption of efficient international capital markets. In addition, due to the focus on the term structure of an open economy estimation of term structures of external economies in separate models is beyond the scope of this paper[6].

[6] Studying term structure model of all economies would involve assessment of currency risk and currency risk premia could be expected to contribute considerably to the variation in yields across economies. This model embraces the possibility of such linkage between currency risk premia and term structure by explicitly incorporating exchange rates into the factors, i.e. using them as sources of market risk. As shown below, the model successfully accounts for the forward premium anomaly and the UIP condition.

As internal and external shocks hit the open economy, yields are driven by the dynamics captured by the factors z_t modelled as the $VECX^*$ system in (2.16). Impact of state variables on yields is assumed to conform with the no-arbitrage condition. More precisely, a process for the short rate can be written as

$$r_t = \delta_0 + \delta_1' z_t \tag{2.19}$$

and the nominal pricing kernel[7] as

$$\begin{aligned} M_{t+1} &= \exp\left(-r_t - \frac{1}{2}\lambda_t' H \Sigma_{\zeta\zeta} H' \lambda_t - \lambda_t' H \zeta_{t+1}\right) \\ &= \exp\left(-\delta_0 - \delta_1' z_t - \frac{1}{2}\lambda_t' H \Sigma_{\zeta\zeta} H' \lambda_t - \lambda_t' H \zeta_{t+1}\right) \end{aligned} \tag{2.20}$$

λ_t are the market prices of risk, which are assumed to be affine in the underlying state variables z_t, i.e.

$$\lambda_t = \lambda_0 + \lambda_1 z_t \tag{2.21}$$

In order to keep the model parsimonious, I restrict the market prices of risk to depend only on contemporaneous observations of the series in the $VECX^*$ model. To that end I assume that both domestic variables as well as their foreign counterparts are being priced[8].

In an arbitrage-free market, the price of a n-months to maturity zero-coupon bond in period t must equal the expected discounted value of the price of an $(n-1)$-months to maturity bond in period $t+1$

$$p_t^{(n)} = E_t\left[M_{t+1} p_{t+1}^{(n-1)}\right] \tag{2.22}$$

Since yields are affine in the state variables, bond prices $p_t^{(n)}$ are exponential linear functions of the state vector

[7] I define the dynamics of the nominal pricing kernel in line with the structure introduced in Duffie and Kan (1996) and applied, among others, by Ang and Piazzesi (2003), Hördahl et al. (2006) and Moench (2008). The pricing kernel is a process

$$M_t = \exp\left(-r_t\right) \frac{\psi_{t+1}}{\psi_t}$$

with ψ_t denoting the Radon-Nikodym derivative that transforms the equivalent martingale measure into the physical measure. ψ_t is assumed to follow the lognormal process $\psi_{t+1} = \psi_t \exp\left(-\frac{1}{2}\lambda_t' \bar{\Omega} \lambda_t - \lambda_t' \bar{\varepsilon}_{t+1}\right)$ and is driven by the shocks $\bar{\varepsilon}_t$ in the state variables characterized by the covariance matrix $\bar{\Omega}$.

[8] It should be noted that in this formulation the domestic stochastic discount factor (or pricing kernel) does depend upon foreign sources of uncertainty. This statement conforms with the general result of asset pricing models for open economies which argue that foreign risk aversion matters for the domestic asset prices. In addition, international asset pricing models, that are typically constructed as the aggregation of a family of standard (single-country) models such as, for example, the Capital Asset Pricing Model (CAPM), usually postulate some degree of market integration, i.e. significance of foreign or international sources of risk.

$$p_t^{(n)} = \exp\left(A_n + B_n' z_t\right) \tag{2.23}$$

where the scalar A_n and the vector B_n depend on the time to maturity n. Therefore, following Ang and Piazzesi (2003), no-arbitrage restriction holds when A_n and B_n are computed recursively by following equations

$$A_n = A_{n-1} + B_{n-1}'\left(\mu - H\Sigma_{\zeta\zeta}H'\lambda_0\right) + \frac{1}{2}B_{n-1}'H\Sigma_{\zeta\zeta}H'B_{n-1} - \delta_0 \tag{2.24}$$

$$B_n = B_{n-1}'\left(\{\Phi_i\} - H\Sigma_{\zeta\zeta}H'\lambda_1\right) - \delta_1' \tag{2.25}$$

where $\{\Phi_i\}$ denotes the companion form of the parameter matrix on the vector of lagged state variables, defined in Equation (2.18), in case of the system in Equation (2.16) with lag order $p > 1$. Given the price of an n-months to maturity zero-coupon bond, the corresponding yield is thus obtained as

$$y_t^{(n)} = -\frac{\log p_t^{(n)}}{n} = a_n + b_n' z_t \tag{2.26}$$

where $a_n = -A_n/n$, $A_0 = \delta_0$ and $b_n = -B_n'/n$, $B_0 = \delta_1$ define the parameters in the last equation[9].

Altogether, the term structure model of an open economy is an affine term structure model that has $VECX^*$ as a state equation and it is completely characterized by equations (2.6), (2.8) and (2.16) along with (2.24)-(2.26).

2.2.2 Data

I estimate the model for the Swiss economy. A set of domestic variables

$$x_t = \{e_t, gdp_t, \pi_t, r_t, cpi_t - cpi_t^*\}$$

contains a trade-weighted exchange rate (e_t), real output (gdp_t), inflation (π_t), a short term interest rate (r_t) and the ratio of domestic to foreign price levels ($cpi_t - cpi_t^*$). The underlying variables are built in a following way:

$$e_t = \ln\left(\sum_{j=1}^{M} w_j FX_{jt}\right), \quad gdp_t = \ln(GDP_t/CPI_t), \quad r_t = R_t/1200$$

$$\pi_t = \ln(CPI_t/CPI_{t-1}), \quad cpi_t = \ln\left(CPI_t\right)$$

where

CPI_t = consumer price index during period t,

FX_{jt} = spot exchange rate with country j,

[9] See Appendix for derivations.

R_t = nominal short-term rate of interest per annum,

GDP_t = nominal gross domestic product,

M = number of partner economies,

w_j = trade-based weight of country j.

A set of country-specific foreign variables consists of selected domestic variables' counterparts

$$x_t^* = \{gdp_t^*, r_t^*, d_t\}$$

and (the log of) the oil price (d_t) which is assumed to be exogenous for the base economy.

The dataset runs from July 1991 until September 2009 on a monthly frequency[10]. It comprises Bloomberg data for exchange rates and IMF's International Financial Statistics data for output at market prices and consumer price indices. Quarterly GDP is interpolated from monthly industrial production (from IMF's IFS and Eurostat) using technique proposed in Salazar et al. (1997) and Mitchell et al. (2005), except for Switzerland, where no GDP index is employed[11]. Utilizing industrial production as the only indication of GDP may lead to exaggeratedly volatile output figures, however, since for many countries no reliable monthly data on consumption, private services or public spending is readily available, industrial production aggregates are uniformly used to preserve some degree of consistency throughout the data. When not previously performed, series are adjusted for seasonality using the Census X12 procedure[12].

Yield data for maturities of 1, 3, 6, 12, 24, 60 and 120 months are taken from Bloomberg and include interbank interest rates for maturities up to 1 year and swap rates for longer maturity horizons. Oil prices are represented by DJ UBS-Crude Oil Total Return Sub-Index.

The $VECX^*$ model in this paper resorts to trade-based weights for the purpose of construction of foreign-specific variables[13]. Trade weights are computed from IMF's Direction of Trade Statistics quarterly data for the period from Sep. 1990 until Sep. 2009

[10] The sample begins in July 1991 due to the fact that no data for interest rates for longer maturities were available prior to that date.

[11] As opposed to data-based techniques which in general rely on mathematical interpolation, Salazar et al. (1997) and Mitchell et al. (2005) present a model-based approach which refers to methods developed by Chow and Lin (1971, 1976) and makes explicit use of conditional expectations.

In short, the authors assume that the hypothetical vector of high frequency endogenous variables which are observed only in low frequency can be linked to strictly exogenous regressors (indicators) by a linear model. This regression is then solved by minimizing the sums of squares of the residuals subject to the constraint that the interpolated high frequency values in each sub-period sum up to the known low frequency totals. The model is estimated numerically by solving non-linear first order conditions subject to some initial values and the desired degree of accuracy.

[12] See page http://www.census.gov/srd/www/x12a/ for more information.

[13] Due to importance of the financial sector for the Swiss economy financial weights, or a mixture of them and the trade-based weights, should theoretically provide a better choice. Bank for International Settlements (BIS) reports, as a part of BIS Quarterly Review (tables 9B and 6A), cross-country bank lending exposure data which could be used as a proxy of financial (or banking) linkages between countries. However, those data are not available for all partner economies of Switzerland for the time period under study.

for Switzerland's 10 most important trading partners: Germany, France, Italy, the United States, the United Kingdom, Austria, the Netherlands, Japan, Spain and Sweden. For the purpose of estimation average weights from the sample are put to use.

Since the data in the model stretch for almost 20 years, structural breaks are quite likely to be found in the time series. Even though the $VECX^*$ models tend to be quite robust to the possibility of structural change as compared to reduced form VARs, I perform several stability tests following Dees et al. (2007) and consider statistics that are based on the residuals of the individual equations of the country-specific error correction models. To this account I include maximum OLS cumulative sum (CUSUM) statistic of Ploberger and Kraemer (1992) (denoted as PK sup) as well as its mean square version (PK msq), tests for parameter constancy against non-stationary alternatives proposed by Nyblom (1989) and, finally, sequential Wald type tests of a one-time structural change at an unknown change point. The latter tests include Quandt (1960) likelihood ratio statistic (QLR), the mean Wald statistic of Hansen (1992) and a test based on the exponential average proposed by Andrews and Ploberger (1994) (APW). In addition, heteroscedasticity-robust version of the tests are reported.

Table B.2 in Appendix presents results of the tests computed at the 5% significance level; critical values are derived from bootstrap samples. The tests document some evidence of structural instability in the data. In particular, inflation and price level differential seem to undergo structural changes. However, when robust variant of the statistics are considered, it becomes more apparent that the instability tends to mainly affect error variances. In order to deal with the problem of unstable error variances I use robust standard errors when investigating the impact effects of foreign variables and impulse response functions.

2.2.3 Estimation

Estimation procedure in this paper follows the consistent two-step approach suggested by Ang et al. (2006). First, estimates of parameters $(\mu, \{\Phi_i\}, \Sigma_{\zeta\zeta})$ governing the dynamics of the model factors are obtained by running $VECX^*$. Second, given the estimates from the first step, the parameters λ_0 and λ_1 which drive the evolution of the state prices of risk are estimated by minimizing the sum of squared fitting errors of the model.

Estimation of the $VECX^*$ model in the first step involves:

- constructing country-specific foreign variables x_t^*, where $x_t^* = \sum_{j=1}^{M} w_j x_{jt}$, M denotes the number of partner economies and w_j the weight of country j,
- selection of an appropriate lag order,
- identification of the cointegration rank given existence of $I(1)$ variables and subject to reduced rank restriction; $VECX^*$ model from (2.16) is estimated in its error-correction form using Johansen's reduced-rank procedure (Johansen (1992)

and Johansen (1995)). In particular, cointegrating vectors are assumed to be exactly identified and the regression is performed by restricting the trend coefficients into the cointegrating space, while allowing the intercept coefficients to be unrestricted in levels,

- ML estimation of the long-run parameters β from (2.12) subject to over-identifying restrictions; estimates of β under exactly identifying restrictions are herewith used as a starting point.

This procedure considers economically meaningful over-identifying restrictions that conform with theoretical priors. To that end I run preliminary sub-system ARDL regressions of the four long-run relations I might find in the data: purchasing power parity (PPP), output gap between domestic and foreign output (GAP), uncovered interest rate parity between domestic and foreign interest rate (UIP) and long-run interest rate rule (LIR). Except for LIR all coefficient estimates are significant and have the expected signs[14]. Thus, in accordance with those preliminary results of tests for existence of long-run relationsships between variables in the data, I impose PPP, GAP and UIP:

$$\begin{aligned}
\text{PPP:} \quad & e_t - (cpi_t - cpi_t^*) = \alpha^{PPP} + \varepsilon_t^{PPP} \\
\text{GAP:} \quad & gdp_t = \alpha^{GAP} + \beta^{GAP} gdp_t^* + \varepsilon_t^{GAP} \\
\text{UIP:} \quad & r_t - r_t^* = \alpha^{UIP} + \varepsilon_t^{UIP}
\end{aligned}$$

In the second step of the model estimation, for a given set of parameters $\left(\hat{\mu}, \{\hat{\Phi}_i\}, \hat{\Sigma}_{\zeta\zeta}\right)$, the model implied yields $\hat{y}_t^{(n)} = \hat{a}_n + \hat{b}_n' z_t$ are computed and the sum of squared errors (S) is minimized with respect to λ_0 and λ_1 where S is given by

$$S = \sum_{t=1}^{T}\sum_{n=1}^{N}\left(\hat{y}_t^{(n)} - y_t^{(n)}\right)^2 \tag{2.27}$$

In order to achieve fast convergence of (2.27) I adopt procedure from Moench (2008): first, parameters λ_0 are estimated assuming that risk premia are constant over time, i.e. λ_1 are zero. Then these estimates are taken as starting values in the second round of estimation in which all parameters λ_0 and λ_1 are evaluated freely.

Order of integration

The underlying assumption of the $VECX^*$ model estimation is that of the unitary order of integration for all variables included in the model. Table 2.1 presents results for augmented Dickey-Fuller GLS test proposed by Elliot et al. (1996).

Not surprisingly, exchange rate, output, short term interest rate and oil price are unambiguously $I(1)$ processes. In case of inflation its test statistic suggests no unit root in levels. Yield spread and price level differential, on the other hand, are considered not

[14] See Appendix for results of ARDL regressions.

Table 2.1: ADF-GLS unit root test results

	$y_t^{(120)} - \bar{r}$	e_t	gdp_t	π_t	r_t	$cpi_t - cpi_t^*$	gdp_t^*	r_t^*	d_t
level	-1.81	-1.64	-0.52	-3.72	-1.11	-1.80	0.39	-1.11	-1.58
Δ	-2.18	-2.80	-2.09	-1.67	-4.03	-0.84	-4.69	-4.05	-3.72
Δ^2	-1.37	-2.76	-0.99	-0.93	-1.54	-0.53	-2.11	-5.06	-22.31

Note: Statistics for level variables are based on regressions including linear trend; statistics for first and second differences include only intercept term. The 95% critical values are -3.4328 and -1.9422, respectively.

to be stationary in first differences. Overall, however, it seems reasonable to regard most of the series under consideration approximately as $I(1)$ variables.

Testing weak exogeneity

Another assumption of the model - weak exogeneity of the country-specific foreign variables x_t^* - can be tested by running first-difference regressions of the foreign variables and testing the joint significance of the country-specific error-correction terms in these regressions. This translates to conducting following regression for each element l of x_t^*

$$\Delta x_{t,l}^* = \mu_l + \sum_{j=1}^{r} \gamma_{j,l} ECM_{t-1}^j + \phi_l \Delta x_{t-1} + \theta_l \Delta x_{it-1}^* + \varepsilon_{t,l} \tag{2.28}$$

where ECM_{t-1}^j are the estimated error-correction terms associated with the r cointegrating relations. The hypothesis of joint significance, $\gamma_{j,l} = 0$, is verified by means of an F-test.

Table 2.2: Results of F-tests for weak exogeneity

critical value	gdp_t^*	r_t^*	d_t
3.087	0.547	**4.472**	0.170

Note: Bold numbers denote significance at 5%.

Weak exogeneity is not rejected for foreign output and the oil price. In case of foreign short term interest rate the F-test results support rejection of null hypothesis of weak exogeneity at 5%. This result may suggest a stronger financial rather than real linkage of the Swiss economy with the rest of the world. In fact, in the wake of tightening trade and financial interdependencies among economies it would be reasonable to assume most or even all macroeconomic variables to be endogenously determined, as the number of countries under study grows.

2.2.4 Identification of shocks

The structural cointegrated approach presented in this paper builds upon variables directly observed in the economy. Contrary to DSGE modelling, which - for the purpose of derivation of the long-run, steady-state relations of the macroeconomics - starts with the intertemporal optimization problem faced by the agents of the economy and solves the Euler first order conditions, $VECX^*$ works directly with the arbitrage conditions which provide intertemporal links between prices and asset returns. DSGE approach's strength lies in the explicit identification of unobserved macroeconomic disturbances as shocks to tastes, technology, policy, demand or supply so that a statement on the form of the short-term dynamics can be formulated; this is, however, achieved at the expense of strong assumption regarding the functional form of underlying processes. $VECX^*$, on the other hand, assumes that the economic theory is more likely to provide a coherent guide to the long-run characteristics of the macroeconomy and it is less confident about the short-term dynamics.

The difficulty of the structural cointegrated VAR approach concerns the disability to account for the identification of the shocks which are unobservable by nature. However, if it is the case that economic theory is insufficiently well-defined to provide credible identifying restrictions on the short-run behaviour of economic agents, this approach can be capable of providing sufficient information about the dynamics of the model as well as being informative about the consequences of shocks rather than the precise reasons behind their occurance. By using generalized impulse response functions $VECX^*$ provides a method of coherent analysis of shocks in observable macroeconomic aggregates which is invariant to the ordering of the variables. From this point of view, the structural cointegrated VAR analysis does not require economic identification of shocks. The identification problem arises only when it is further required to decompose the effects of the shocks in the observed variables into unobserved theoretical concepts. In this case VAR approach has to be accompanied by additional restrictions from the economic theory.

Following the exposition in Garratt et al. (2006), a more detailed a priori modelling of expectations, production, consumption, technology etc. and of the short-run dynamics is required. That is, further restriction must be placed on the contemporaneous relationships among variables, for instance, to a model given in equation (2.2):

$$A\Delta z_t = \bar{a}_0 + \bar{a}_1 t - \bar{\alpha}\beta' z_{t-1} + \sum_{i=1}^{p-1} \bar{\Gamma}_i \Delta z_{t-i} + \epsilon_t \tag{2.29}$$

where A represents a matrix of contemporaneous structural coefficients, $\bar{a}_0 = Aa_0$, $\bar{a}_1 = Aa_1$, $\bar{\alpha} = A\alpha$, $\bar{\Gamma}_i = A\Gamma_i$, and $\epsilon_t = Au_t$ are the structural shocks (for instance, to policy rate or to technology) which are serially uncorrelated and have zero means and a positive definite covariance marix $\Omega = A\Sigma A'$. Restrictions on A incorporate description of decision rules followed by the agents and identify their use of information and the exact timing of the information flows[15].

In a structural vector autoregression framework, using restrictions on the contemporaneous relationships between variables, as captured by the matrix A, can be combined with other methods of identification of shocks. Dungey and Fry (2009) nest three identification methods, short-run restrictions, sign restrictions and long-run restrictions, in a model with fiscal, monetary and other macroeconomic variables. In particular, they use short-run restrictions on the non-fiscal variables, identify fiscal policy shocks using a minimal set of sign restrictions and leave other relationships to be determined by data. These restrictions are then applied in conjunction with information from the cointegrating relationships between macroeceonomic variables to model the long run in a way that accounts for both permanent and transitory shocks in a model with both stationary and non-stationary data and allows the use of cointegrating relations as a means of identification as in Pagan and Pesaran (2008).

Another aspect of the identification of shocks in a $VECX^*$ model concerns the exact identification of shocks of all observable variables - both demestic and foreign. To that end, Dees et al. (2007) propose identification scheme of Sims and Zha (2006) where different ordering of variables is considered.

2.3 Model properties

2.3.1 In-sample fit

Figure 2.1 shows observed yields together with their fitted counterparts. In general, the model is able to recover observed data, however, its ability to do so weakens with the increasing maturity horizon. Apparently, the model fails to adequately account for high volatility at the long end of the yield curve; in other words, variables in the $VECX^*$ model lack a factor that would properly explain changes in time of the slope of the term structure.

Therefore, in order to induce a better fitting of the yield curve I introduce a new factor, yield spread measured as $y_t^{(120)} - \bar{r}$, i.e. long-term yield adjusted by the long-run mean of the short-term interest rate, into the underlying model of macro factors[16]. As a result of

[15] Garratt et al. (2006) in chapters 5 and 10 elaborate on implementation of such restrictions in case of a monetary policy shock. Identification of this disturbance includes a formulation of the monetary authority's decision problem, a derivation of the policy rate, an expression of the policy rate's reaction function and, finally, a specification of the structural interest rate equation.

[16] Note that $y_t^{(120)} - \bar{r}$ can easily be computed but it is not directly observed by the agents of the economy. Therefore there is no inconsistency in pricing of yields between equations (2.16) and (2.26) when this factor is considered, since $y_t^{(120)} - \bar{r}$ is assumed to be observed with measurement error. However, if $y_t^{(120)} - r_t$ would instead be introduced into the underlying model of macro factors, additional constraints on a_n and b_n should be imposed so that under both (2.16) and (2.26) $y_t^{(120)}$ is consistently priced:

$$a_{120} = 0, \quad b_{120} = \theta_1 + \theta_2$$

where θ_1 and θ_2 are vectors of zeros with a 1 in the first and fifth element, respectively. Yet, estimation of a model with many macroeconomic factors (i.e. possibly high column size of b_n in case of VAR in companion form) and yields ranging to very long maturities together with non-linear constraints (due to

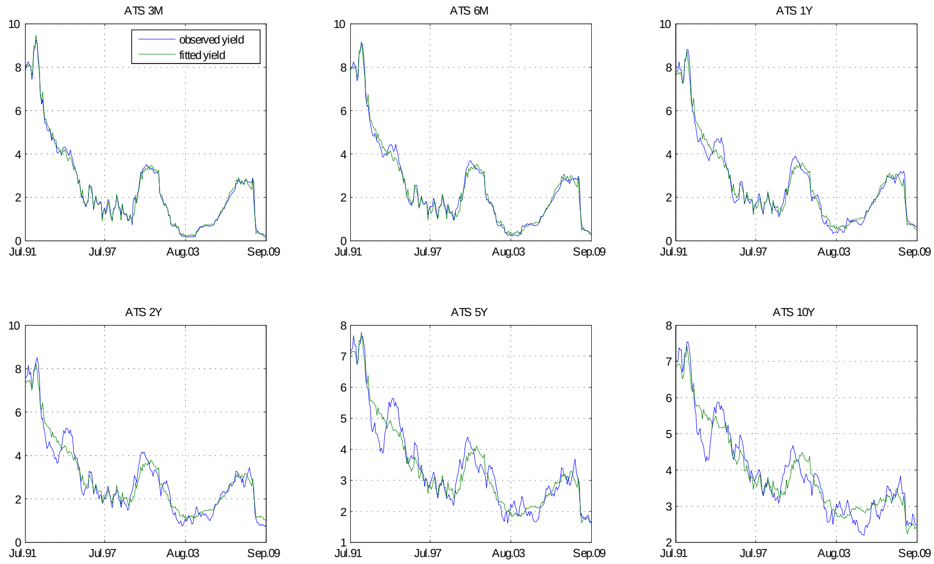

Figure 2.1: In-sample fit of the yield curve from the $VECX^*$ affine term structure model.

this amendment the set of domestic variables changes to

$$x_t = \left\{ y_t^{(120)} - \bar{r}, e_t, gdp_t, \pi_t, r_t, cpi_t - cpi_t^* \right\}$$

As shown in Figure 2.2, direct modelling of the slope enhances the ability of the model to reproduce the actual term structure.

Overall, the model fits the data well even though it does not involve any latent yield curve factors as traditional affine models do. After having explicitly accounted for the slope of the yield curve, it captures the cross-sectional variation of the yields aptly, with a somehow better in-sample fit at the short and the long end of the yield curve.

2.3.2 Expectation hypothesis tests

Expectation hypothesis states that the yield on an n-period bond should increase when the spread between the same yield and the short-term rate widens. This means that a regression of the yield change $y_{t+1}^{n-1} - y_t^n$ on the yield spread $(y_t^n - r_t) / (n-1)$ should produce a coefficient of 1. However, numerous empirical studies found a significant negative relationship which gets more negative for increasing maturities. As the study of Campbell and Shiller (1991) shows for the US data, those regression coefficients can be as

the fact that a_n and b_n have to be computed recursively) does not seem to be computationally practicable.
As Joslin et al. (2010) show, imposition of the no-arbitrage restriction will not influence the conditional forecasts of the pricing factors in any canonical Gaussian dynamic term structure model. They argue that an improvement in forecasting would rather come from auxiliary constraints on the physical distribution of the pricing factors, such as the number of risk factors that determine risk premia, for instance. In this paper, results from the out-of-sample yield projections confirm empirically this claim.

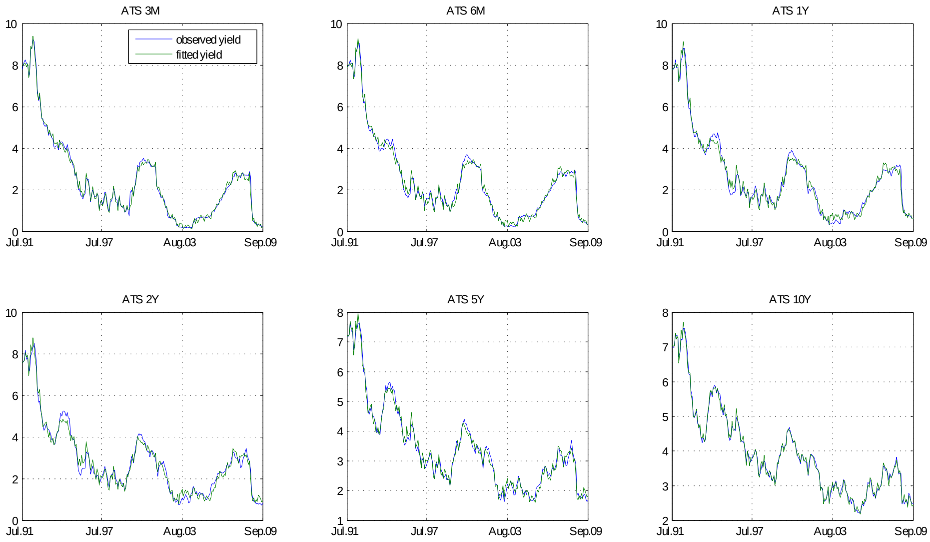

Figure 2.2: In-sample fit of the yield curve from the $VECX^*$ affine term structure model with the yield spread.

big as -5 for 10-year bond.

In an attempt to reconcile this finding with the predictions implied by the expectations hypothesis Dai and Singleton (2002) show that a large subclass of affine dynamic term structure models generates such negative regression coefficients. They document that the risk premiums (and associated expected excess holding period returns $er_t^n = E_t\left[\ln\left(p_{t+1}^{n-1}/p_t^n\right) - r_t\right]$) implied by affine term-structure models with unobservable factors match the values of the coefficients obtained from OLS regressions on actual yield data (they denote this test als $LPY\,(i)$). In addition, Dai and Singleton (2002) are able to recover the coefficients of unity, that are consistent with the expectation hypothesis, by running regressions of the risk-premium adjusted yield changes $y_{t+1}^{n-1} - y_t^n + er_t^n/\,(n-1)$ onto the yield spread (test denoted as $LPY\,(ii)$). In this paper, I follow this approach and estimate both types of the Campbell and Shiller-like regressions:

$$\begin{aligned} LPY\,(i) \quad &: \quad y_{t+1}^{n-1} - y_t^n = const. + \phi_n\left[\left(y_t^n - r_t\right)/\left(n-1\right)\right] + residual \\ LPY\,(ii) \quad &: \quad y_{t+1}^{n-1} - y_t^n + er_t^n/\left(n-1\right) = const. + \phi_n^*\left[\left(y_t^n - r_t\right)/\left(n-1\right)\right] + residual \end{aligned}$$

where by using short interest rate equation (2.19) and the bond pricing formula (2.22) one-period holding premium e_t^n can be written as:

$$er_t^n = \left(B_{n-1}' H \Sigma_{\zeta\zeta} H' \lambda_0 - \frac{1}{2} B_{n-1}' H \Sigma_{\zeta\zeta} H' B_{n-1}\right) + \left(B_{n-1}' H \Sigma_{\zeta\zeta} H' \lambda_1\right) z_t \tag{2.30}$$

Table 2.3: Campbell-Shiller regression results for the sample data

$y_{t+1}^{n-1} - y_t^n = const. + \phi_n \left[(y_t^n - r_t) \,/\, (n-1) \right] + residual$						
			whole sample			
maturity	3M	6M	12M	24M	60M	120M
ϕ_n	-0.607	-0.654	-0.860	-0.209	0.277	-0.026
s.e.	(0.234)	(0.363)	(0.514)	(0.693)	(1.062)	(1.393)
t-stat($\phi_n = 0$)	-2.590	-1.803	-1.671	-0.301	0.260	-0.018
t-stat($\phi_n = 1$)	-6.857	-4.559	-3.615	-1.745	-0.681	-0.736
			first half of the sample			
ϕ_n	-0.239	-0.209	0.138	0.154	1.176	0.369
s.e.	(0.378)	(0.545)	(0.722)	(0.923)	(1.386)	(1.701)
t-stat($\phi_n = 0$)	-0.633	-0.384	0.192	0.167	0.849	0.217
t-stat($\phi_n = 1$)	-3.277	-2.220	-1.194	-0.917	0.127	-0.371
			second half of the sample			
ϕ_n	-1.667	-1.706	-3.302	-2.327	-3.156	-1.320
s.e.	(0.267)	(0.495)	(0.831)	(1.299)	(1.947)	(2.750)
t-stat($\phi_n = 0$)	-4.371	-3.444	-3.969	-1.792	-1.621	-0.480
t-stat($\phi_n = 1$)	-8.118	-5.462	-5.171	-2.562	-2.135	-0.844

Note: s.e. is the estimated standard error; t-statistics are reported for $H_0 : \phi_n = 0$ and $H_0 : \phi_n = 1$.

Table 2.3 shows results of the $LPY(i)$ test on the sample data. When the whole sample is taken into account, the evidence seems to be less compelling than results of Campbell and Shiller (1991). Except for the horizon $n = 60$, the estimated slope coefficient tends to negative but it is not decreasing with maturity. In general, the expectations hypothesis puzzle appears to be less severe for the Swiss data under study when compared to the data for the US-yields reported by both Campbell and Shiller (1991) and Dai and Singleton (2002).

Though conforming with results for European data as reported by Hardouvelis (1994), Gerlach and Smets (1997), Bekaert and Hodrick (2001) and Hördahl et al. (2006), for instance, the validity of this finding appears to be limited in the light of evidence coming from results of regressions run for sub-samples of the Swiss data. As shown in Table 2.3, slope coefficient derived from regression for the first part of the data tends to positive and rising whereas the coefficient for the second half of the data gets far more negative. Notably, this effect is most pronounced for long-term maturities which are modelled with swap rates. This may be an issue of the quality of the data on the swap rates, which might actually have not been available in the past but could have instead been generated using the expectations hypothesis assumptions[17].

Furthermore, when tested under $LPY(i)$, the model does not seem to generate the pattern observed in the sample data, at least not in the case of short maturities. As

[17] I cross-check these results by estimating the Campbell and Shiller-like regressions using another set of data, obtained from the Swiss National bank, and find similar parameter estimates. As before, the coefficient on the yield spread does not decrease with maturity and it tends to be positive for longer horizons, especially in the first half of the sample.

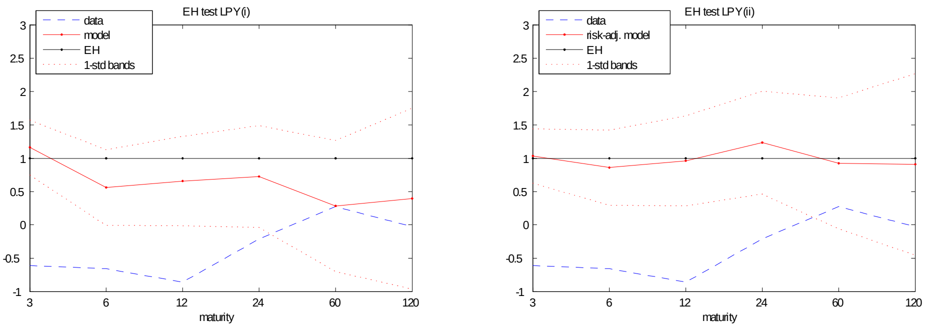

Figure 2.3: Campbell-Shiller regression results for the model implied data.

presented in Figure 2.3, the model implied coefficient ϕ_n tends to be positive and not significantly different from 1. However, the good news is that the model succeeds in fulfilling the $LPY(ii)$ test and it is able to reproduce the coefficients implied by the expectations hypothesis[18].

2.3.3 Term structure and exchange rate risk premium

The same factors that determine risk premia of interest rates in domestic and foreign currencies may possibly affect risk premium in exchange rates. Yields and exchange rates may both depend on expectations about the same macroeconomic variables. Recent macroeconomic literature on interest rates and exchange rates[19] suggests therefore to examine interest rates and exchange rates jointly. This paper facilitates a similar approach since both the exchange rate (e_t) as well as the foreign short-term interest rate (r_t^*) are among the macroeconomic factors. I examine the relation between term structure and exchange rates by analysing the forward premium anomaly and by estimating the model implied exchange rate risk premia.

The forward premium anomaly for one period ahead is characterized by the following regression from Fama (1984):

$$e_{t+1} - e_t = \alpha_e + \beta_e \left(r_t - r_t^*\right) + \varepsilon_{t+1}^e \tag{2.31}$$

where e_t is the logarithm of nominal exchange rate (E_t) and $r_t - r_t^*$ is the interest rate differential between domestic and foreign one-period interest rate. Uncovered interest rate parity predicts that $\overset{\wedge}{\alpha}_e = 0$ and $\overset{\wedge}{\beta}_e = 1$, however, Fama (1984) and others document the point estimates of beta that are negative which constitutes the existence of the forward

[18]As already indicated by Hördahl et al. (2006), the success of the model in matching LPY depends on the assumptions related to the market prices of risk. Specifically, the λ_1 matrix which links variations in prices with different sources of risk plays a crucial role in the performance of the model in terms of the $LPY(i)$ test. For instance, it turns out that the interactions generated by some off-diagonal elements of λ_1 are very important. However, in this paper I do not pursue an analysis of the statistical significance of the elements of this matrix as proposed by Duffee (2002) but instead let all elements of λ_1 enter the estimation.

[19]See for instance Backus et al. (2001), Dewachter and Maes (2001) or Diez de los Rios (2009).

premium anomaly. Consistent with the literature I obtain in case of the monthly data used in this paper $\hat{\beta}_e = -3.50$ with a 95% confidence interval of $[-6.90, -0.08]$. Using the parameter estimates from the model I simulate exchange rates 10.000 times and find the mean of $\hat{\beta}_e = -3.49$ and the corresponding 95% confidence interval = $[-4.73, -2.39]$. Thus the model successfully replicates empirical findings and accounts for the forward premium anomaly.

If markets are complete, exchange rates equalize the differences between domestic and foreign pricing kernels, M_t and M_t^*, respectively. Backus et al. (2001) show that the exchange rate obeys the no-arbitrage condition and can be derived for one holding period as:

$$\Delta e_{t+1} = m_{t+1}^* - m_{t+1} \tag{2.32}$$

where small scripts denote logs.

Using Equation (2.20) for the nominal pricing kernel allows to write down the expected change in exchange rate from Equation (2.32) as:

$$\begin{aligned}
\Delta e_{t+1} &= (r_t - r_t^*) + \frac{1}{2}\left(\lambda_t' H \Sigma_{\zeta\zeta} H' \lambda_t - \lambda_t^{*\prime} H \Sigma_{\zeta\zeta} H' \lambda_t^*\right) + \left(\lambda_t' H - \lambda_t^{*\prime} H\right) \zeta_{t+1} \\
E_t\left[\Delta e_{t+1}\right] &= (r_t - r_t^*) + \frac{1}{2}\left(\lambda_t' H \Sigma_{\zeta\zeta} H' \lambda_t - \lambda_t^{*\prime} H \Sigma_{\zeta\zeta} H' \lambda_t^*\right)
\end{aligned}$$

The expected change in exchange rate equals to the difference $r_t - r_t^*$ between the domestic and foreign exchange rates and the foreign exchange risk premium, which is a quadratic function of macroeconomic factors z_t and is determined by the same risk factors as the term structure of interest rates. In a risk neutral world, with $\lambda_t = \lambda_t^* = 0$, UIP suggests that the expected change in exchange rate equals the interest rate differential. On the other hand, UIP should hold when accounted for the exchange risk premium.

In this specification, shocks to macroeconomic factors, represented by $\Sigma_{\zeta\zeta}$, influence both the domestic and foreign markets. Transmission channel of shocks is therefore determined by the structure imposed on the model in Equation (2.16). In particular, foreign variables affect equilibria of the domestic economy and they additionally influence the domestic variables contemporaneously. On the other hand, shocks in the domestic variables do not alter the equilibria in the foreign economy, however, lagged changes of both domestic and foreign variables are allowed to affect it. As expected, I find that regressing the risk adjusted change in exchange rate on the interest rate differential, in analogy to Equation (2.31), allows to recover positive values of beta. While beta from this regression generally does not equal unity, obtaining positive beta does not seems to depend on the specification of foreign market prices of risk. In general, however, the condition specified in Equation (2.32) is only valid under the assumption of complete markets; with the international financial markets being not complete, it is possible to recover he nominal pricing kernels from asset market data by choosing λ_t and λ_t^* in such a way that Equation (2.32) holds, but this choice will not be unique. As Brandt et al. (2006) show, Equation (2.32) remains valid for the incomplete markets when the market prices of risk are chosen such that the variance of the nominal pricing kernels is minimized. For this case I recover beta parameter estimate $\hat{\beta}_e = 1.19$ with a 95% confidence interval of $[-4.20, 6.58]$.

2.3.4 Dynamics

Generalized impulse response functions

This paper examines the dynamics of the model by undertaking analysis of the generalized impulse response functions (GIRFs). In this application, two different shocks are simulated:

- a negative one standard error shock to the domestic GDP,
- a positive one standard error shock to the foreign short term interest rate.

The scope of this simulation is to assess the impact of shocks in macroeconomic variables on interest rates. In addition, since Swiss economy is linked to its partner economies, this analysis should provide insights on how cross-boarder spillovers propagate and how they affect yields. In what follows I therefore concentrate on responses of the term structure.

GIRFs, as proposed by Koop et al. (1996) and developed by Pesaran and Shin (1998) for vector error-correcting models, differ from Orthogonalized Impulse Response Functions (OIRFs) in that they do not orthogonalize residuals of the system but instead take historical correlations among variables into consideration, captured by the estimated variance-covariance matrix. Thus, contrary to OIRFs, GIRFs do not require any economic restrictions and they are invariant to the ordering of the variables in the system. To that respect, GIRFs provide insight on how shocks propagate between countries and variables and unveil potential macroeconomic interdependence between economies. However, since the shocks are not identified, GIRFs do not supply information about the causal relationships among variables. Nevertheless, this disadvantage seems to be negligible compared to the difficulty of applying OIRFs in a multilateral context, since there is practically no reasonable and intuitive method to order many countries in the model.

Negative one standard error shock to domestic GDP As Figure 2.5 depicts, responses of interest rates to a negative one standard deviation shock in GDP are uniformly negative, persistent and significant only in the short-run. Yields react with a sudden drop, which is pronounced at most in the middle of the yield curve, and then settle around the level of a third of the initial impact. The longer the maturity is, the less perceptible is this pattern of reaction. In general, the impact of GDP shock on yields is very limited.

The pattern of response across maturities comes to some degree at a surprise, since one would expect the volatility weight to rest overwhelmingly on the short end of the yield

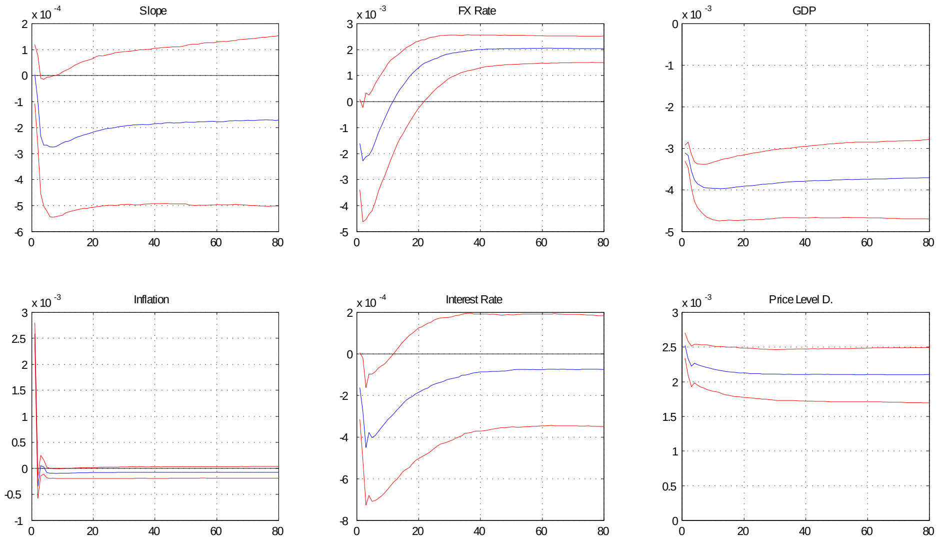

Figure 2.4: Impulse responses of macro factors to a negative one standard error shock to domestic GDP, with 68% confidence bands.

curve rather than in the middle of it. Presumably this phenomenon can be attributed to the fact, that only 1-month and 120-month yields interact with macro factors directly through relationships modelled in the $VECX^*$ system whereas the remaining ones connect via market prices of risk, that could be misspecified to some extent.

Positive one standard error shock to foreign short term interest rate Contrary to previous perturbation, a positive one standard deviation shock to the foreign short term interest rate has a significant impact (at the 68% confidence level) over the whole impulse response horizon across the yields up to 60-months. In addition, performance pattern of yields is similar in scale but decreasing in magnitude across maturities. Yields rise uniformly, with the biggest increase for 1-month interest rate up to a level of 200 basis points. The overall magnitude of impact at the long end of the yield curve is much smaller - approaching a range between 20 and 25 basis points.

Generalized forecast error variance decomposition

Generalized forecast error variance decomposition (GFEVD) shows to what extent return variability in one variable can be explained by the innovations from other aggregates in a VAR system. Results of this analysis for yields in case of one standard error shock to domestic GDP are reported in Table 2.4.

The data point at quite different dynamic behavior of interest rates across maturities. In the first two periods following domestic GDP shock, is can be observed that the real ouput contribution to the forecast error variance appears to be evenly spread between

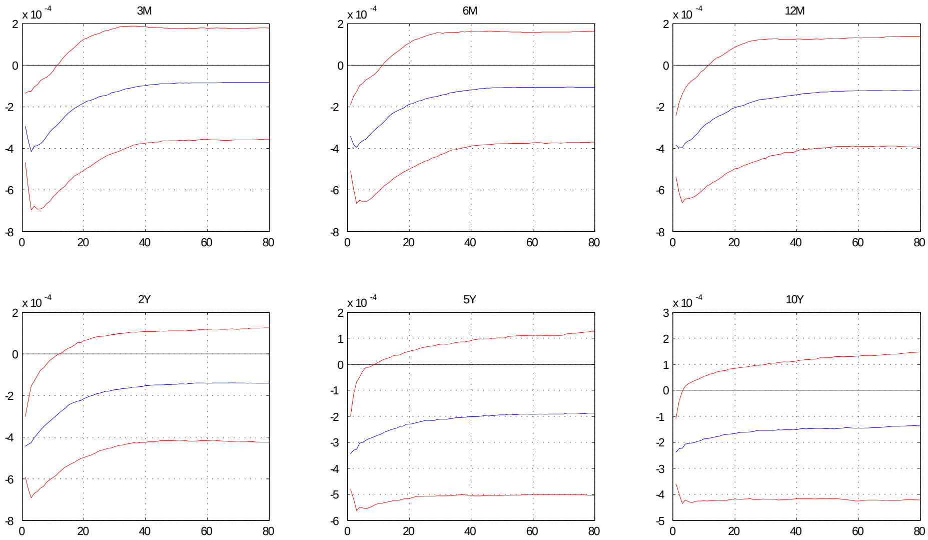

Figure 2.5: Impulse responses of yields to a negative one standard error shock to domestic GDP, with 68% confidence bands.

yields in the short run. However, In the long run the relative contribution of the ouput shock tends to propagate towards one maturity block only: 12/24-month horizon. In addition, the contribution patterns differ between yields: 1-, 12- and 24-month maturities have U-shaped forecast error variance patters, 3- and 6-month horizons show decresing ones whereas long-term maturities are characterized by bell-shaped like variance patterns. In seems that in the short run real output shock contribution to the forecast error variance affects primarily short-term yields, but then it shifts to the long-term block of maturities and eventually it recedes towards the middle of the yield curve.

Table 2.4: GFEVD: a negative one standard error shock to domestic GDP

		Months								
		0	1	2	6	12	24	36	48	60
Yields	1M	0.65	0.25	0.20	0.09	0.27	0.42	0.45	0.44	0.42
	3M	0.93	0.41	0.36	0.14	0.05	0.05	0.06	0.05	0.05
	6M	1.31	0.45	0.42	0.31	0.21	0.17	0.16	0.16	0.17
	12M	1.76	0.47	0.46	0.72	1.17	1.41	1.46	1.49	1.50
	24M	2.23	0.68	0.71	1.45	2.59	3.15	3.26	3.29	3.29
	60M	0.53	1.04	1.05	0.90	0.53	0.30	0.25	0.23	0.23
	120M	0.00	0.62	0.59	0.32	0.09	0.04	0.04	0.04	0.03

Note: Percentage of k-step ahead forecast error variance of the historical shock to foreign short term interest rate. Percentages do not sum up to 100 since 113 grid points of the yield curve are omitted.

Table 2.5 reports GFEVD following a positive one standard error shock to foreign short term interest rate. In this case for both short-run and the long-term the relative

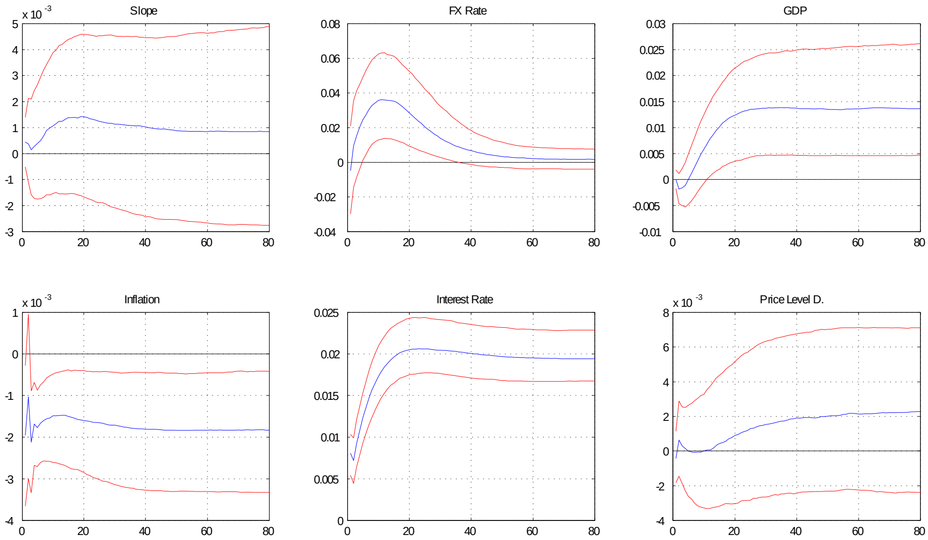

Figure 2.6: Impulse responses of macro factors to a positive one standard error shock to foreign short term interest rate, with 68% confidence bands.

contribution to the forecast error variance tends to spread to yields of maturities between 6 and 24 months and it seems to stay quite stable over time. In general, the most of the variance after the foreign interest rate shock can be attributed to the yields in the middle of the curve; notably, 1- and 120-month yields remain almost unaffected by the short term foreign interest rate shock.

Table 2.5: GFEVD: a positive one standard error shock to foreign short term interest rate

		Months								
		0	1	2	6	12	24	36	48	60
Yields	1M	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	3M	0.08	0.09	0.10	0.11	0.11	0.12	0.12	0.13	0.13
	6M	0.59	0.61	0.62	0.63	0.63	0.63	0.63	0.64	0.65
	12M	1.99	1.97	1.95	1.90	1.89	1.88	1.88	1.88	1.88
	24M	3.20	3.14	3.09	3.02	3.00	2.99	2.97	2.96	2.96
	60M	0.23	0.26	0.28	0.31	0.32	0.33	0.33	0.34	0.34
	120M	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01

Note: Percentage of k-step ahead forecast error variance of the historical shock to foreign short term interest rate. Percentages do not sum up to 100 since 113 grid points of the yield curve are omitted.

2.4 Out-of-sample forecasts

Forecasting performance is examined over the time interval from June 2001 to September 2009. It is a rolling exercise, i.e. at each time point t model parameters Θ =

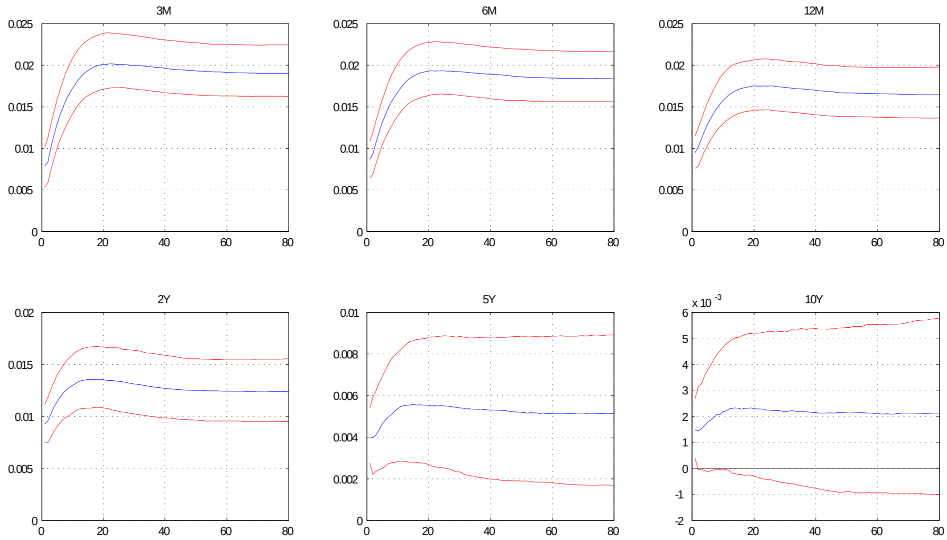

Figure 2.7: Impulse responses of yields to a positive one standard error shock to foreign short term interest rate, with 68% confidence bands.

$\{\mu, \{\Phi_i\}, \Sigma_{\zeta\zeta}, \lambda_0, \lambda_1\}$ are estimated and k-month forecast of the yield curve is calculated. At each later point in time $t+j$ the model is re-estimated using the same number of observations and yields for k-horizon are forecast. RMSE from the Nelson-Siegel model (NS), as specified in Diebold and Li (2006), serves as benchmark. In particular, the benchmark model can be written in state space form as

$$\begin{aligned} y_t^{(n)} &= H\beta_t + u_t \\ \beta_t &= \kappa + F\beta_{t-1} + v_t \end{aligned}$$

where the yield curve factors are enclosed in $\beta_t = (level_t, slope_t, curvature_t)'$, matrix H collects factor sensitivities, $u_t \sim iid\,(0, \sigma_u)$, $v_t \sim iid\,(0, \sigma_v)$ and the model is solved using Kalman filter. NS is a not arbitrage-free term structure model widely used in finance, known for its sound out-of-sample forecasting performance. As Table 2.7 reveals, NS is capable of exceptionally good yield curve fitting.

Table 2.6 summarizes RMSE ratios relative to the benchmark model obtained from the forecasts. In several cases the model outperforms NS specification. Generally speaking, it works better for shorter maturities and mid-term forecasting horizons. In particular, it outperforms NS for 1-month yield in forecasts 2 up to 12 months ahead; for 3, 6 and 12-month yields in forecasts 3 up to 12 months ahead; and for 12, 60 and 120-month yields in forecasts 6 and 12 months ahead. The model tends to retain comparable predictive power with NS across all yields for longer forecasting horizons; it fails however at the 1-month ahead horizon.

Table 2.6: Out-of-sample term structure forecasts

		Yields						
		1M	3M	6M	12M	24M	60M	120M
Horizon	1 month	1.073	1.160	1.216	1.355	1.473	1.269	1.225
	2 months	0.960	1.011	1.017	1.073	1.186	1.103	1.080
	3 months	0.867	0.903	0.905	0.926	1.027	1.025	1.033
	6 months	0.846	0.873	0.857	0.848	0.949	0.989	0.970
	9 months	0.894	0.907	0.884	0.853	0.917	0.960	0.944
	12 months	0.949	0.952	0.926	0.887	0.914	0.931	0.900
	18 months	1.069	1.059	1.034	0.998	1.020	1.014	0.941

Note: Table entries are RMSE ratios relative to the Nelson-Siegel model; the out-of-sample period is Jun. 2001 to Sep. 2009.

In order to assess the empirical importance of openness I compare the results of estimation and the forecasting power of the baseline model for the open economy to a specification for a closed economy. The closed economy model consists of a vector error-correction system that includes domestic slope factor, GDP, inflation and short-term interest rate, and omits all foreign variables:

$$x_t = \left\{ y_t^{(120)} - \bar{r}, gdp_t, \pi_t, r_t \right\}$$

The system is estimated in analogy to Equation (2.6) by exploring long-run relations between domestic variables only. Table 2.7 shows a comparison of the sums of squared fitted errors from Equation (2.27) for the model for an open and closed economy. Even though the closed economy model is more parsimonious and attains a very good fit of the 3-month and 120-month maturities, it misses a lot of information about the term structure of yields for maturities in between. Foreign macroeconomic factors seem to improve the ability of the model to capture the dynamics of the curvature of the term structure considerably. It can also be observed that the fit obtained for the open economy model improves a lot when foreign macroeconomic factors are taken into account, i.e. when the market prices of risk are not restricted to domestic factors only.

As shown in Table 2.8, out-of-sample forecasting performance of the ATS model of a closed economy is weak in terms of RMSE and considerably inferior when compared to its peers. Though improving with the projection horizon, the forecasting results do not match even nearly those of the NS model or the open economy ATS model. In particular, the magnitude of error increases for short projection horizons and the short end of the yield curve, which points at a poor ability of the $VECM$ system to account for the dynamics of the domestic short-term interest rate. Overall, these findings call into question the standard closed economy macro-finance specification of the term structure.

Table 2.7: Term structure fit

	Yields							
	1M	3M	6M	12M	24M	60M	120M	total
NS Model	2.15	0.60	0.81	1.53	1.20	1.37	0.76	8.42
ATS Closed Economy	0.00	4.33	10.07	21.87	26.95	17.54	0.62	81.38
ATS Open Ec., restr.	0.00	8.80	15.31	24.33	40.03	34.05	35.14	157.66
ATS Open Ec., unrestr.	0.00	5.15	8.03	11.89	12.98	5.45	1.76	45.26

Note: Table reports sum of squared errors from the estimation of market prices of risk for a given maturity horizon (in squared percentage points). SSE are reported for Nelson-Siegel model and affine term structure models of a closed economy, an open economy with market prices of risk restricted to domestic factors only and an open economy with market prices of risk that include both domestic and foreign macroeconomic factors.

Table 2.8: Out-of-sample term structure forecasts for the closed economy model

		Yields						
		1M	3M	6M	12M	24M	60M	120M
Horizon	1 month	10.88	10.30	8.96	6.63	4.48	3.31	3.99
	2 months	11.80	11.08	9.15	6.71	4.71	3.73	4.39
	3 months	11.62	10.41	8.56	6.24	4.56	3.83	4.48
	6 months	7.87	7.01	5.89	4.57	3.78	3.52	3.77
	9 months	4.65	4.17	3.66	3.19	2.92	3.00	3.08
	12 months	2.97	2.77	2.59	2.49	2.35	2.53	2.73
	18 months	2.20	2.11	2.03	2.01	1.92	2.11	2.39

Note: Table entries are RMSE ratios relative to the Nelson-Siegel model; the out-of-sample period is Jun. 2001 to Sep. 2009.

2.5 Conclusion

This paper presents a model of the term structure for an open economy based on the idea that domestic capital markets of an open economy are closely related to their external counterparts. Therefore, the paper argues that the external macroeconomic factors influence significanly the domestic term structure of yields. To account for the influence of spillovers from abroad and their effects on domestic transmission channels between monetary policy, economic activity and asset prices, a structural cointegrated VAR approach is used to model macroeconomic factors, short rate and yield spread. Then the term structure is built given restrictions implied by the no-arbitrage condition. Contrary to previously proposed macro-finance models of the term structure, the model suggested here explicitly accounts for financial and real spillovers between economies.

Put to data for the Swiss economy, the model explains the dynamics of yields well. It also does a good job at predicting yields out-of-sample. It outperforms Nelson-Siegel model across all maturities and for horizons up to 12 months ahead. In addition, the model facilitates a relation between yields and exchange rates and accounts for the forward premium anomaly. Moreover, it is capable of capturing the implifications of the uncovered interest rate parity by recovering positive coefficients on interest rate differential between domestic and foreign short-term interest rates once the exchange rate risk premium is considered. The model specification for a closed economy fares far worse in terms of both the forecasting performance and the term structure fit which underlines the importance of openness in modeling the dynamics of the term structure.

The model presented in this paper could be further improved by a more elaborate modelling of the underlying market prices of risk. Improvements in terms of better predicting power could also be expected once short-term dynamics in the $VECX^*$ model of macro factors are estimated subject to restrictions using Bayesian priors. This model can also be integrated within a Global VAR (GVAR) setup so that the term structures of foreign economies could be examined simultaneously with the yield curve of the base economy.

Chapter 3

Decoupling of Economies? Evidence from a Global VAR Analysis of Regional Spillovers

3.1 Introduction

During past decades economies have undoubtedly become more intertwined and complex. In the course of globalization, national borders and regional differences have proved to be less relevant as businesses increasingly started to operate in a single global market. As the process of increasing economic interdependence advanced, emerging markets have constantly increased their share in the world productive activity and account now for roughly a quarter of world output and a major share of the global growth. Their share of total world exports is almost 50%; they consume over a half of the world's energy and generate four-fifths of the growth in oil demand. With economies becoming more interlinked through flow of goods and money across national borders, emerging markets tie closer together with the developed countries, making both more dependent on each other's economic performance.

Yet what recent developments in the global economy made apparent is that some economies seem to divert. Output figures reported in mid 2009 by Asia's emerging economies and BRICs (a widely used acronym referring to Brazil, Russia, India and China) showed an impressive bounce, while the US GDP still fell. It seems that when America suffers from financial crisis, emerging economies slow down but they are unlikely to be derailed; economic growth in emerging markets is observed to hold up even in face of a global downturn and it shows signs of a strong recovery while developed economies still suffer from economic turmoil. Such evidence for emerging markets clearly runs against the idea of increased synchronization of business cycles across the world.

Stronger trade and financial linkages should contain decoupling of markets through integration of the real economy and consolidating effects of financial interconnections. Decreasing transport costs of shipping, declining tariffs, internationally integrated production, widely accessible information about production opportunities in foreign countries and international movement of workers - all that makes the world more closely correlated. Global financial markets tend to be even more tightly linked - through a rise in cross-country listings, cross-border ownership, international composition of equity and bond portfolios, to name just a few factors. Financial channels of integration tend to play an important role in transmission of shocks between economies. For instance, tightening liquidity conditions lead to banks pulling out their assets what quickly transmits the shocks abroad.

In the many channels of the international distribution of shocks commodity prices count as important means of transmission of spillovers. Shocks to those common global factors may put additional strain on economies; yet an increased demand for commodities benefits their suppliers, i.e. emerging markets, and helps to offset the effects of weakening exports to developed countries. On the other hand, falling prices of commodity stocks in the wake of recession can have damaging effects on exports and output of commodity producers. In case of financial markets, new correlations across financial assets and limited impact of disruptions on emerging economies are being observed. Emerging markets show performance patterns in stock prices similar in scale to those of the developed countries; they tend to rebound quicker and their financial markets appear to be less volatile than previously known.

After all, having more integration and less synchronization at the same time does not have to be so much of a contradiction. International trade tends to promote specialization which weakens the correlation between economies. In addition, globalization and decoupling can be reconciled once such factors as improved financial and political policies, lower inflation due to improved monetary policy, improvement in the fiscal discipline and large currency reserves in the emerging markets have been taken into account. As many emerging economies are turning from being net foreign borrowers to net lenders with current account surpluses, they tend to be less vulnerable to capital outflows than they used to be. Moreover, many emerging markets have a nearly balanced budgets which leave enough room for a fiscal stimulus in case of an economic downturn.

Recent empirical studies, however, do not provide unambiguous guidance concerning the impact of increased trade and financial linkages on the co-movement among macroeconomic aggregates across countries. They also present different conclusions about the temporal evolution of co-movement properties of the main macroeconomic variables. Kalemli-Ozcan et al. (2003) look at the financial linkage and suggest that it can result in a higher degree of business cycle co-movement by generating large wealth effects. However, financial links can also decrease the cross-country output correlations since they promote specialization of production through the reallocation of capital according to countries' comparative advantage. Helbling and Bayoumi (2003), Heathcote et al. (2004) and Doyle and Faust (2005) find no change or even falling correlations between macroeconomic aggregates of G-7 countries over time. Kose et al. (2003), on the other hand, study the correlations between the fluctuations in individual country aggregates (output, consumption, and investment) for a sample of 76 economies and suggest that both trade and financial linkages have a positive impact on cross-country output and consumption correlations. Imbs (2006) shows that financial sector contributes to an increase in international correlations in both consumption and GDP fluctuations, with the latter effect being larger than the former. Kose et al. (2008) employ a Bayesian dynamic latent factor model in order to examine changes in business cycles over time and document that the degree of comovement of business cycles of major macroeconomic aggregates across the G-7 countries has increased during the globalization period. Akin and Kose (2008) examine the nature of growth spillovers between developed economies and developing countries driven by the process of rising international trade and financial flows. They find evidence of a falling impact of the economic activity in industrial economies on the developing countries and document a set of stylized facts that indicate intensifying intra-group growth spillovers. As a result, the nature of economic interactions between those groups of countries is said to "have evolved from one of dependence to multidimensional interdependence". Study of Kose et al. (2008) gives support to the idea that business cycle among industrial economies and among emerging ones converge within each group, but it also finds evidence for divergence between those groups. Rising trade and financial integration seem not to be associated with global convergence in business cycles but instead lead to emergence of group-specific cycles. However, by taking only fluctuations in a few macroeconomic variables into consideration, the paper focuses on the real side of the economies only and it lacks incorporation of financial aggregates.

The objective in this paper is to evaluate the degree of synchronization or decoupling in international business cycles across economies within a global vector autoregressive model (GVAR). This study relates to the empirical literature on international business cycles and economic spillovers between countries, in particular to Akin and Kose (2008) and Kose et al. (2008), and it also builds on the econometric literature on GVAR models. As with respect to the latter, it draws from Pesaran et al. (2004), Pesaran and Smith (2006) and Dees et al. (2007), where global VAR models were applied to analyse international interdependencies using trade-based linkage parameters. It also relates to the research work of Galesi and Sgherri (2009), where financial weights based on BIS data[1] were used, the focus, however, was limited to the USA and a number of European economies only. My paper puts the questions of decoupling and globalization into the GVAR framework. It extends the existing research program by enriching the panel dimension of the model (40 countries under analysis are grouped into several regions according to the MSCI Barra classification) and by including both financial and trade-based linkage in order to model the international interdependencies in a more precise way. Set of variables comprises of aggregates for the real sector as well as the financial one and property markets. Oil price index is included as a common global variable.

[1] Bank for International Settlement (BIS) disseminates consolidated banking sector statistics for on-balance sheet financial claims on the rest of the world. The quarterly data cover contractual lending by the head office and all its branches and subsidiaries on a worldwide consolidated basis.

In order to accommodate the possibility of structural breaks in data, which is readily potential given the time span and the cross-country dimension of the model, I conduct tests of structural stability of parameters and analyse the impact of different weighting schemes used to produce foreign country-specific variables. Furthermore, to address a frequent critique of utilizing constant or averaged weights in GVAR systems I incorporate time-varying weights into the model and set up a submodel for weights which can be used for projections of changes in interlinkages between countries in the impulse response analysis. This model allows for feedback between macroeconomic variables and weights and thus accounts for the dynamic character of links between economies. In essence, employing time-varying weights leads to time-varying parameters of the GVAR system.

In general, GVAR models are specifically designed to account for an interaction between large number of countries and spillovers between real and financial sectors. This framework allows to study macroeconomic relationships and financial linkages through such variables as interest rates and equity prices and provides a comprehensive tool for analysis of cointegration among financial markets and real sectors. Therefore, by employing this estimation tool I expect to address the following questions: Are there commonalities in the dynamics of the real and financial aggregates across countries and regions? What is the impact of both trade and financial linkages on the global business cycles?

The analysis in this paper is concerned with the international transmission channels of real and financial shocks. First of all, this transmission mechanism includes the impact of international trade on the aggregate supply and demand. Changes in disposable income and real exchange rates across economies influence terms of trade and the demand in the domestic economy. Growth in foreign liquidity or income raises demand for domestic goods and currency leading to a strengthening of the domestic currency in value. The second transmission channel operates through financial interrelations. Impact of financial linkages relates to capital flows that simply follow return differentials. Higher real rates of return on domestic assets, e.g. interest rates, equity returns and real estate property values, stimulate the demand for domestic currency as more investors favor investing in the domestic market. Increases in domestic inflation rates and income, on the other hand, cause the demand for foreign goods to raise and the purchasing power to fall. Third, financial aggregates respond to changes in business cycles and expectations about future real activity, both domestic and foreign. On the other hand, financial conditions, e.g. interest rates and asset prices, influence economic growth though credit cycles and wealth accumulation. Moreover, the rising prominence of emerging economies re-orders the international transmission channels in that it adds specific macroeconomic factors that presumably influence the global business cycles. Those factors include high economic growth and rapidly increasing base of the global demand, but also underdeveloped financial markets, higher inflation, exchange rate and capital controls and a specific structure of exports.

In this paper, I report two major results about the degree of synchronization among developed, emerging and frontier economies. First, the findings suggest that the development in international financial markets and cross-border trade activity seem to expand the transmission of shocks abroad and to amplify business cycle fluctuations to regions where the integration is greater, especially as a result of asset price movements. Impulse responses of real sectors tend to mildly support the idea of decoupling of economies, showing evidence of slightly different paths of economic performance across regions. Second, financial linkages tend to substantially alter the dynamics of the macroeconomic aggregates across economies by adding moderation and, to some extent, more disattachement among regions. As more countries join the single global market, new linkage constellations and spillover patterns emerge. Contrary to the convergence hypothesis, rising trade-based and financial linkages seem to partly endorse group-specific business cycles. However, parameter uncertainty and nuanced but substantial impact of the modeling strategy in construction of weakly exogenous variables must be taken into account when interpreting the results.

This paper is organized as follows. Section 2 contains a brief description of GVAR framework, discusses the outcome of Monte Carlo experiments and presents structural stability tests of the data used in the analysis. Section 3 reports results of the estimation of the model, including the analysis of dynamic characteristics through impulse responses and variance decompositions. Section 4 elaborates on counterfactuals and the model for time-varying weights while the last section concludes.

3.2 Methodology and data

The spillover effects are modelled in a GVAR approach that follows Pesaran et al. (2004), and Dees et al. (2007). This model admits inclusion of a relatively large number of countries and modeling co-movement in financial and real variables. In this approach individual vector error correction models are linked to each other by country-specific foreign variables in each country's VAR.

Empirical models usually suffer from heavy parametrization when the number of countries is relatively large compared to the time dimension. Global macroeconomic literature proposes two methods of dealing with this problem: (*i*) data shrinkage, as for instance in factor models, (*ii*) shrinkage of the parameter space, e.g. as developed in spatial models. However, those methods in general and the factor models in particular have the disadvantage that they bring about identification problems or information loss. Factor models usually do not use or test for long-run cointegrating relations and loose therefore a lot of the long-run information contained in data. Estimated factors tend to be difficult to interpret in economic terms, particularly when there are many variables for many countries. In addition, factors that are crucial for one country may get ignored when accounting for only a small part of the global variance. Increasing the number of factors reduces the attraction of the procedure and makes the interpretation of results more difficult. GVAR models, on the other hand, address all those shortcomings; they represent a way to overcome the dimensionality problem by modeling links between countries through foreign variables calculated as averages of macroeconomic aggregates of the partner economies. They have the advantage of employing foreign variables with a natural theoretical interpretation and using the information in trade patterns or financial linkages. Moreover, GVAR models allow a transparent long-run theoretical structure and permit testing and imposing, if necessary, short-run overidentifying theoretical restrictions.

In my paper country-specific foreign variables are constructed by means of both trade-based and financial weights so that the importance of the flow of good and money has been accounted for. Mixed weights are calculated according to the relative size of the financial sector in a country as indicated by stock market capitalization, private bond market capitalization and bank assets relative to GDP. Using mixed weights represents an original contribution to the GVAR modeling framework; Pesaran et al. (2004) and Dees et al. (2007) employ weights based on cross-country trade flows while Galesi and Sgherri (2009) use financial weights only. Vansteenkiste (2007) uses weights based on geographical distances whereas Hiebert and Vansteenkiste (2007) adopt weights calculated from sectoral input-output tables for various industries.

3.2.1 Structure of the model

The GVAR model presented here comprises of 40 countries which are modelled individually as vector autoregressions. Each country's VAR embeds country domestic variables x_{it}, country-specific foreign variables x_{it}^* and a global common variable d_t, whereas the latter two are assumed to be weakly exogenous to the global economy[2]. In particular, each country i is modelled as a $VARX^*(p, q, s)$, that is a VAR augmented by weakly exogenous $I(1)$ variables, with p, q and s being lag order terms for x_{it}, x_{it}^* and d_t respectively; in case of $VARX^*(1, 1, 1)$, presented here for the sake of simplicity, the model is given by

$$x_{it} = a_{i0} + a_{i1}t + \Phi_i x_{it-1} + \Lambda_{i0} x_{it}^* + \Lambda_{i1} x_{it-1}^* + \Psi_{i0} d_t + \Psi_{i1} d_{t-1} + \varepsilon_{it} \tag{3.1}$$

for $t = 1, 2, ..., T$ and $i = 1, 2, ..., N$. Φ_i is a $k_i \times k_i^*$ matrix of coefficients associated to lagged domestic variables, Λ_{i0} and Λ_{i1} are $k_i \times k_i^*$ matrices of coefficients related to contemporaneous and lagged foreign variables, respectively, while Ψ_{i0} and Ψ_{i1} are $k_i \times s$ matrices of coefficients associated to contemporaneous and lagged global common variable. a_{i0} is a $k_i \times 1$ vector of fixed intercepts, a_{i1} is a $k_i \times 1$ vector of coefficients of the deterministic time trend and ε_{it} is a a $k_i \times 1$ vector of country-specific shocks assumed to be serially uncorrelated with a zero mean and a non-singular covariance matrix $\mathbf{\Sigma}_{ii} = \sigma_{ii,lm}$ where

[2] Weak exogeneity refers to foreign variables in the sense that they affect the domestic variables contemporaneously but they are not affected by disequilibria in the domestic economy. However, foreign variables could be affected by lagged changes of domestic and foreign variables. Technically speaking, in error correcting regressions of changes in foreign variables in the model none of the lagged error correction terms associated with the domestic economy should be statistically signifficant. Therefore - in the context of partial single–country sub-systems of the GVAR - weak exogeneity differs from the notion of "Granger (Non)Causality" which would imply that none of the domestic variables be allowed to enter the regression for the foreign variables. Granger and Lin (1995) refer to weakly exogenous $I(1)$ variables as "long-run" forcing.

$\sigma_{ii,lm} = cov(\varepsilon_{ilt}, \varepsilon_{imt})$ and

$$\varepsilon_{it} \sim i.i.d.\,(\mathbf{0}, \mathbf{\Sigma}_{ii}) \tag{3.2}$$

It is also assumed that

$$E\left(\varepsilon_{it}, \varepsilon'_{jt'}\right) = \begin{Bmatrix} \mathbf{\Sigma}_{ij} & for & t = t' \\ \mathbf{0} & for & t \neq t' \end{Bmatrix} \tag{3.3}$$

which allows for cross-country correlation among the idiosyncratic shocks. As a result, GVAR model facilitates interactions among the different economies through (i) contemporaneous relationship between domestic variables x_{it}, foreign country-specific variables x^*_{it} and a global common variable d_t, with their lagged values and (ii) contemporaneous interrelation between the shocks in country i and the shocks in country j, as characterized by the cross-country covariances $\mathbf{\Sigma}_{ij}$, where $\mathbf{\Sigma}_{ij} = cov(\varepsilon_{it}, \varepsilon_{jt}) = E\left(\varepsilon_{it}, \varepsilon'_{jt'}\right)$, for $i \neq j$.

The global VAR representation arises directly from the individual country-$VARX^*$ equations. After grouping both the domestic and the foreign-specific variables in one vector

$$z_{it} = \begin{pmatrix} x_{it} \\ x^*_{it} \end{pmatrix} \tag{3.4}$$

each country's model can be rewritten as

$$A_i z_{it} = a_{i0} + a_{i1}t + B_i z_{it-1} + \Psi_{i0} d_t + \Psi_{i1} d_{t-1} + \varepsilon_{it} \tag{3.5}$$

where

$$A_i = (I_{k_i}, -\Lambda_{i0}) \text{ and } B_i = (\Phi_i, \Lambda_{i1}) \tag{3.6}$$

Then, by grouping all domestic variables in one vector

$$x_t = \begin{pmatrix} x_{1t} \\ x_{2t} \\ \vdots \\ x_{Nt} \end{pmatrix} \tag{3.7}$$

and due to the fact that country specific foreign variables are constructed as weighted averages it is possible to express following identity

$$z_{it} = W_i x_t \ , \qquad\qquad i = 1, 2, ..., N \tag{3.8}$$

where W_i is a country-specific link matrix constructed on basis of mixed financial and trade statistic-based weights.

Reformulation of (3.5) leads to following equation

$$A_i W_i x_{it} = a_{i0} + a_{i1} t + B_i W_i x_{it-1} + \Psi_{i0} d_t + \Psi_{i1} d_{t-1} + \varepsilon_{it} \tag{3.9}$$

and, finally, to the GVAR(1) model by simply stacking all country equations to

$$G x_t = a_0 + a_1 + H x_{t-1} + \Psi_0 d_t + \Psi_1 d_{t-1} + \varepsilon_t \tag{3.10}$$

where

$$a_0 = \begin{pmatrix} a_{10} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix}, \quad a_1 = \begin{pmatrix} a_{11} \\ a_{11} \\ \vdots \\ a_{N1} \end{pmatrix}, \quad \varepsilon_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix} \tag{3.11}$$

$$G = \begin{pmatrix} A_1 W_1 \\ A_2 W_2 \\ \vdots \\ A_N W_N \end{pmatrix}, \quad H = \begin{pmatrix} B_1 W_1 \\ B_2 W_2 \\ \vdots \\ B_N W_N \end{pmatrix}, \quad \Psi_0 = \begin{pmatrix} \Psi_{10} \\ \Psi_{20} \\ \vdots \\ \Psi_{N0} \end{pmatrix}, \quad \Psi_1 = \begin{pmatrix} \Psi_{11} \\ \Psi_{21} \\ \vdots \\ \Psi_{N1} \end{pmatrix} \tag{3.12}$$

Provided that G matrix is not singular, one can restate the model as

$$x_t = b_0 + b_1 + F x_{t-1} + \Upsilon_0 d_t + \Upsilon_1 d_{t-1} + u_t \tag{3.13}$$

where

$$b_0 = G^{-1} a_0 \ , \quad b_1 = G^{-1} a_1 \ , \quad F = G^{-1} H \ , \quad \Upsilon_0 = G^{-1} \Psi_0 \ , \quad \Upsilon_1 = G^{-1} \Psi_1 \ , \quad u_t = G^{-1} \varepsilon_t \tag{3.14}$$

3.2.2 Estimation

Due to a considerable dimension of the GVAR model, estimation of (3.13) cannot be accomplished by means of a standard VAR estimation procedure. It would involve evaluation of a number of parameters that cannot be supported even for high values of T[3]. However, this complication can be tackled in a special procedure that rests upon estimation of each country's partial model separately and computation of the country specific weights w_{ij} from the empirical data (rather than getting their estimates out of the model). This procedure can be justified when following conditions hold:

[3] High N-dimension leads to problems with consistent estimation of the model and issues of endogeneity of country-specific country variables. The literature suggests to either shrink the parameter space or deflate the data in order to guarantee consistency. Chudik and Pesaran (2009) propose - for so called infinite-dimensional VARs (IVAR) - to shrink part of the parameter space in the limit as the number of endogenous variables (N) tends to infinity. Bussiere et al. (2009), on the other hand, pay particular attention to the modeling strategy; they test the number of long-run relationships in different subsets of country-specific models.

- The global model is dynamically stable, i.e. eigenvalues of the matrix F lie either on or inside the unit circle,
- The weights w_{ij} used to construct foreign variables x^*_{it} are relatively small such that

$$\sum_{j=0}^{N} w_{ij}^2 \longrightarrow 0 \;, \quad \text{as } N \longrightarrow \infty \;, \quad \forall i \tag{3.15}$$

- The cross-dependence of the idiosyncratic shocks must be sufficiently small

$$\frac{\sum_{j=1}^{N} \sigma_{ij,lm}}{N} \longrightarrow 0 \;, \quad \text{as } N \longrightarrow \infty \;, \quad \forall i, l, m \tag{3.16}$$

where $\sigma_{ij,lm} = cov(\varepsilon_{ilt}, \varepsilon_{jmt})$ is the covariance of the variable l in the country i with the variable m in the country j.

All of those requirements are met in my GVAR model. First, the model is dynamically stable, as the moduli of the 201 eigenvalues of the F matrix are all within the unit circle. In particular, the number of eigenvalues lying on the unit circle is 53. Second, the mixed weights are relatively small, i.e. they are sufficiently "granular" for each country as none of them is too close to one. The largest observed weights, when taken from the middle of the sample, are 0.6697 for the weight of the USA towards Canada and 0.4449 for Germany towards Austria. Third, the idiosyncratic shocks are weakly correlated; the value for the average correlation from the third condition listed above equals 0.0034.

Overall, estimation of the GVAR model involves:

- constructing country-specific foreign variables x^*_{it},
- selection of the appropriate lag orders of the domestic, foreign and global variables,
- identification of the cointegration rank for each country's model given existence of $I(1)$ variables and subject to reduced rank restriction; each country-$VARX^*$ model from (3.1) is estimated in its error-correction form using Johansen's (Johansen (1992) and Johansen (1995)) reduced-rank procedure. In particular, in the model applied in this paper regressions are performed by restricting the trend coefficients into the cointegrating space, while allowing the intercept coefficients to be unrestricted in levels.

Each country's $VARX^*$ model is estimated under an assumption that a process $\{v_{it}\}_0^\infty$ defined as:

$$v_{it} = \begin{pmatrix} z_{it} \\ d_t \end{pmatrix} = \begin{pmatrix} x_{it} \\ x^*_{it} \\ d_t \end{pmatrix} \tag{3.17}$$

is generated by a vector autoregression for country i

$$\left(I - \sum_{s=1}^{p} D_{is} L^s\right)(v_{it} - \mu - \gamma t) = \epsilon_{it} \tag{3.18}$$

where L stands for a lag operator.

Defining matrices $\Pi_i = (\sum_{s=1}^{p} D_{is} - I)$ and $\Gamma_{is} = -\sum_{k=s+1}^{p} D_{ik}$, the model can be rewritten in its error-correction form as

$$\Delta v_{it} = a_{i0} + a_{i1}t - \Pi_i v_{i,t-1} + \sum_{s=1}^{p-1} \Gamma_{is} \Delta v_{i,t-s} + \epsilon_{it} \tag{3.19}$$

with

$$\begin{aligned} a_{i0} &= -\Pi_i \mu_i + (\Gamma_i + \Pi_i)\gamma_i \\ a_{i1} &= -\Pi_i \gamma_i \\ \Gamma_i &= I - \sum_{s=1}^{p-1} \Gamma_{is} \end{aligned} \tag{3.20}$$

In this specification, matrix Π_i contains long-run multipliers and the matrices $\{\Gamma_{is}\}_{s=1}^{p-1}$ include short-run parameters.

Then, by restricting the trend coefficients into the cointegrating space, while allowing the intercept coefficients to be unrestricted in levels, i.e. $a_{i1} = \Pi_i \kappa_i$, the error-correction equation in each country-$VARX^*(1,1,1)$ model takes following form

$$\Delta x_{it} = c_{i0} - \Pi_i[v_{it-1} - \kappa_i(t-1)] + \Lambda_{i0}\Delta x_{it}^* + \Psi_{i0}\Delta d_t + \varepsilon_{it} \tag{3.21}$$

where

$$v_{it-1} = \begin{pmatrix} z_{it-1} \\ d_{t-1} \end{pmatrix} \quad \text{and} \quad c_{i0} = a_{i0} + \Pi_i \kappa_i \tag{3.22}$$

Matrix Π_i can be written as

$$\Pi_i = \alpha_i \beta_i' = (A_i - B_i, -\Psi_{i0} - \Psi_{i1}) \tag{3.23}$$

where α_i is a $k_i \times r_i$ loading matrix of rank r_i, β_i is a $(k_i + k_i^* + s) \times r_i$ matrix of cointegrating vectors of rank r_i. Π_i specifies the number of long-run relationships that exist among domestic variables x_{it}, country-specific foreign variables x_{it}^* and the common global variable d_t. If no cointegrating relationships exist, (3.21) collapses to a VAR regression in first differences.

The specification of cointegrating relationships affects substantially the stability of the GVAR system as well as the behavior of impulse response functions. Therefore I additionally consider estimation of smaller GVAR systems with different subsets of countries. Since around 8% of foreign country-specific time series are indicated by tests not to be weakly exogenous (as reported in Table C.5 in Appendix) I also examine sub-systems with only some of the foreign variables. Furthermore, I compare the outcome of the Johansen procedure with results of ARDL regressions (for each country i) of long-run relations that may possibly be found in the data, i.e. output gap between domestic and foreign output, uncovered interest rate parity between domestic and foreign interest rate, long-run interest rate rule, domestic and foreign equity premia, long-run relations between domestic and foreign equity and housing markets and long-run relation between domestic credit and GDP. Finally, I conduct Monte Carlo experiments to investigate the issue of the specification of the cointegrating relations further. Results of these MC exercises are reported in Section 2.4.

3.2.3 Identification of shocks

The GVAR approach presented in this paper builds upon variables directly observed in the economy. Contrary to DSGE modeling, which - for the purpose of derivation of the long-run, steady-state relations of the macroeconomics - starts with the intertemporal optimization problem faced by the agents of the economy and solves the Euler first order conditions, $VARX^*$ subsystems work directly with the arbitrage conditions which provide intertemporal links between prices and asset returns. DSGE approach's strength lies in the explicit identification of unobserved macroeconomic disturbances as shocks to tastes, technology, policy, demand or supply so that a statement on the form of the short-term dynamics can be formulated; this is, however, achieved at the expense of strong assumptions regarding the functional form of underlying processes. GVAR approach, on the other hand, accepts that the economic theory is more likely to provide a coherent guide to the long-run characteristics of the macroeconomy and it is less confident about the short-term dynamics.

The difficulty of the GVAR approach concerns the disability to account for the identification of the shocks which are unobservable by nature. However, if it is the case that economic theory is insufficiently well-defined to supply credible identifying restrictions on the short-run behavior of economic agents, this approach can be capable of providing sufficient information about the dynamics of the model as well as being informative about the consequences of shocks. Rather than seeking the precise reason behind the occurrence of shocks, using generalized impulse response functions within GVAR establishes a method of coherent analysis of shocks in observable macroeconomic aggregates which is invariant to the ordering of the variables. From this point of view, the GVAR analysis does not require economic identification of shocks. The identification problem arises only when it is further required to decompose the effects of the shocks in the observed variables into unobserved theoretical concepts. In this case VAR approach has to be accompanied by additional restrictions from the economic theory.

Following the exposition in Garratt et al. (2006), a more detailed a priori modeling of expectations, production, consumption, technology etc. and of the short-run dynamics is required. That is, further restriction must be placed on the contemporaneous relationships among variables, for instance, to a model for country i given in equation (3.19):

$$A_i \Delta v_{it} = \bar{a}_{i0} + \bar{a}_{i1} t - \bar{\alpha}_i \beta_i' v_{i,t-1} + \sum_{s=1}^{p-1} \bar{\Gamma}_{is} \Delta v_{i,t-s} + \omega_{it} \tag{3.24}$$

where A_i represents a matrix of contemporaneous structural coefficients, $\bar{a}_{i0} = A_i a_{i0}$, $\bar{a}_{i1} = A_i a_{i1}$, $\bar{\alpha}_i = A_i \alpha_i$, $\bar{\Gamma}_{is} = A_i \Gamma_{is}$, and $\omega_{it} = A_i \epsilon_{it}$ are the structural shocks (for instance, to policy rate or to technology) which are serially uncorrelated and have zero means and a positive definite covariance matrix $\Omega_i = A_i \Sigma_{\epsilon i} A_i'$. Restrictions on A_i incorporate description of decision rules followed by the agents and identify their use of information and the exact timing of the information flows[4].

In a structural vector autoregression framework, using restrictions on the contemporaneous relationships between variables, as captured by the matrix A_i, can be combined with other methods of identification of shocks. Dungey and Fry (2009) nest three identification methods, short-run restrictions, sign restrictions and long-run restrictions, in a model with fiscal, monetary and other macroeconomic variables. In particular, they use short-run restrictions on the non-fiscal variables, identify fiscal policy shocks using a minimal set of sign restrictions and leave other relationships to be determined by data. These restrictions are then applied in conjunction with information from the cointegrating relationships between macroeceonomic variables to model the long run in a way that accounts for both permanent and transitory shocks in a model with both stationary and non-stationary data and allows the use of cointegrating relations as a means of identification as in Pagan and Pesaran (2008).

Another aspect of the identification of shocks in $VARX^*$ sub-systems of the GVAR model concerns the exact identification of shocks of all observable variables - both domestic and foreign. To that account, Dees et al. (2007) propose identification scheme of Sims and Zha (2006) where different ordering of variables is considered.

3.2.4 Monte Carlo experiments

Monte Carlo experiments are conducted in order to examine properties of cointegration tests and the stability of cointegrating relations among variables. In the baseline Monte Carlo experiment I use the GVAR model parameters as the data generating process for $N = 40$ countries under study. Assuming that the residuals are randomly distributed with variance-covariance matrix equal to the estimate from the data, $R = 10000$ replications of the model are generated and each time number of cointegrating relations is tested using the Johansen procedure. Then, as an alternative to the baseline experiment, a smaller

[4] Garratt et al. (2006) in chapters 5 and 10 elaborate on implementation of such restrictions in case of a monetary policy shock. Identification of this disturbance includes a formulation of the monetary authority's decision problem, a derivation of the policy rate, an expression of the policy rate's reaction function and, finally, a specification of the structural interest rate equation.

For further reference see also Binder et al. (2010).

model of $N' = 10$ countries is considered in order to assess effects of the panel dimension of the GVAR on performance of cointegration statistics. In each case two specifications of both models are allowed for - with lag order specified in advance or determined by an information criterion - so that the impact of augmentation of the VAR by possible lags is taken into account.

In addition, I design further Monte Carlo experiments to address the issue of different specification of weights for foreign variables and to examine the significance of a structural break in data arising from the recent financial crisis. First, I test the impact of weights by running two Monte Carlo simulations - one with trade-based weights and one with a time-varying weighting scheme. Second, by using GVAR parameters and the variance-covariance matrix for a model estimated from the sample that ends in November 2007 I assess robustness of the model with respect to structural breaks in the data. As done before, both the panel dimension (N) as well we the impact of augmentation induced by a possible lag order are taken into consideration. Table C.16 presents results of all MC experiments.

The findings of the baseline experiment suggest that in case of the trace statistic, which has been used to determine the number of long-run relations, the size of the cointegration test is quite poor (10,50%) while the power is good (95,72%). Weak size property means that the trace statistic tends to overestimate the number of cointegrating relations for the model. The outcome of the MC investigation also implies that the trace statistic underperforms slightly the maximum eigenvalue statistic both in terms of size (10,02%) and power (99,40%). However, when a larger subset of countries is considered, performance of the maximum eigenvalue test depletes (size increases to above 17% and power decreases slightly to 98,25%) whereas the trace test retains its qualities for size and improves in power (10,21% and 98,61%, respectively). This result is broadly in line with findings in the literature which suggest that the trace statistic should usually be preferred because it is more robust to departures from the assumption of normality of residuals.

Outcome for the MC experiment with parameter estimates stemming from a shorter data sample does not differ substantially from previous results except for the maximum eigenvalue statistic in case of $N = 10$ countries (8,08% size versus 10,02% and 91,44% power versus 99,40%). Maximum eigenvalue test seems to sporadically outperform the trace statistic, in particular when the cross-country dimension of the model is small. Moreover, using trade-based weights instead of mixed weights does not alter the overall picture of tests' performance; when compared to the baseline experiment, size and power improve for both statistics in case of the smaller sample but they worsen slightly as a result of an increased panel dimension. In addition, Table C.16 shows that using time-varying weights for construction of the foreign variables considerably improves the efficiency of both cointegration tests in case of small N-dimension. Time-varying weights lead to zero-defect power while letting the tests' size to stay largely below 10%. However, as the cross-county dimension increases, size of the maximum eigenvalue statistic weakens by reaching almost 18%.

Overall, it should be noted that these results stem from a specific formulation of the GVAR model which, in reality, must not match the true data generating process. In particular, during all replications correct number of lags was imposed. The evidence in the literature (among others Mackinnon et al. (1999)) documents that the accuracy of the cointegration tests depends heavily on the sample size, the number of lags in the vector autoregression and the data-generating process. Therefore, it can be expected that the true test performance is likely to be worse than the results shown in the first four columns of Table C.16.

As shown in the last four columns of Table C.16, when the assumption of known lag order in the model is alleviated and lag order is allowed to be specified by an information criterion, size and power of cointegration tests tend to worsen, regardless of the weighting scheme or existence of structural breaks. Trace statistic, however, tends to improve in both size and power (for instance in case of the baseline model 11,29% versus 14,37% for size and 96,56% compared to 94,63% for power) as the number of countries in the model (N) increases. Results for the maximum eigenvalue statistic, on the other hand, point at a worse performance of that test when N gets larger and the lag order in the model is not prespecified but instead determined in each replication by a criterion.

3.2.5 Data

A vector of domestic variables

$$x_{it} = \left(eq'_{it}, cc'_{it}, re'_{it}, ir'_{it}, gdp'_{it}\right)' \tag{3.25}$$

contains a real equity price index (eq_{it}), a real credit to economy (cc_{it}), comprising public and private sector loans, a real housing market index (re_{it}), a short term interest rate (ir_{it}) and real output (gdp_{it}). The underlying variables are built in a following way:

$$\begin{aligned} eq_{it} &= \ln(EQ_{it}/CPI_{it}), \qquad cc_{it} = \ln(CC_{it}/CPI_{it}), \qquad re_{it} = \ln(RE_{it}/CPI_{it}), \\ ir_{it} &= 1/12 * \ln(1 + R_{it}/100), \qquad gdp_{it} = \ln(GDP_{it}/CPI_{it}) \end{aligned} \tag{3.26}$$

where
EQ_{it} = nominal equity price index of country i during period t (total return index),
CPI_{it} = consumer price index,
CC_{it} = total nominal credit to economy,
RE_{it} = nominal housing market index,
R_{it} = nominal rate of interest per annum,
GDP_{it} = nominal gross domestic product.

A vector of country-specific foreign variables consists of domestic variables' counterparts

$$x_{it}^* = \left(eq_{it}^{*\prime}, cc_{it}^{*\prime}, re_{it}^{*\prime}, ir_{it}^{*\prime}, gdp_{it}^{*\prime}\right)' \tag{3.27}$$

for all countries except for the base economy in the model (the United States) for which x_{it}^* omits real output gdp_{it}^*. Since the base economy is considered to be dominant, it is expected that its foreign output index is not going to be weakly exogenous. Indeed, test of weak exogeneity re-confirm this assumption later on.

In order to facilitate a possibility of feedback from economies to the common global variable, d_t is assumed to be endogenous for the base economy; in case of the remaining countries it is considered to be exogenous.

The choice of data in this paper conforms with the standard proceedings in the literature except for the fact that in addition to the main macroeconomic aggregates financial variables such as equity prices, housing market indices and short term interest rates are employed. For instance, Kose et al. (2008) concentrate on output, investment and consumption; Imbs (2006) analyse GDP, consumption and merchandise exports; Heathcote et al. (2004) study fluctuation in GDP, consumption, investment, employment and the changes in the US foreign direct investments. The empirical macroeconomic VAR literature, on the other hand, usually includes output, short term interest rates, inflation, equity prices and exchange rates into the analysis[5]. This specification of variables allows to examine the intra-sectoral spillovers between the real activity, credit supply in the economy and the financial system, represented by bond, equity and real estate markets. In this paper, the choice of variables allows to account for the relationship between credit supply, interest rates and output (e.g. increase in investment and output as a result of raising credit supply in response to falling interest rates), reaction of bond (i.e. short term interest rates) and equity markets to output growth, the relation between interest rates, credit supply, and the equity and housing markets (i.e. the influence of liquidity conditions on asset prices), and the interrelationship between the real activity and commodity prices.

The dataset runs from January 1999 until March 2009 on a monthly frequency. It comprises Bloomberg data for stock prices (MSCI country indices) and 1-month interbank interest rates. The data on total credit to economy, output at market prices and consumer price indices come from IMF's International Financial Statistics. Quarterly GDP is interpolated from the monthly industrial production (from IMF's IFS and Eurostat) using technique proposed in Salazar et al. (1997) and Mitchell et al. (2005), except for Australia, where no GDP index is employed[6]. Utilizing industrial production as the only

[5] See for instance Pesaran et al. (2004), Dees et al. (2007) and Galesi and Sgherri (2009).

[6] As opposed to data-based techniques which in general rely on mathematical interpolation, Salazar et al. (1997) and Mitchell et al. (2005) present a model-based approach which refers to methods developed by Chow and Lin (1971, 1976) and makes explicit use of conditional expectations.

In short, the authors assume that the hypothetical vector of high frequency endogenous variables which are observed only in low frequency can be linked to strictly exogenous regressors (indicators) by a linear model. This regression is then solved by minimizing the sums of squares of the residuals subject to the constraint that the interpolated high frequency values in each sub-period sum up to the known low frequency totals. The model is estimated numerically by solving non-linear first order conditions subject to some initial values and the desired degree of accuracy.

indication of GDP may lead to exaggeratedly volatile output figures, however, since for many countries no reliable monthly data on consumption, private services or public spending is readily available, industrial production aggregates are uniformly used to preserve some degree of consistency throughout the data. When not previously performed, series are adjusted for seasonality using the Census X12 procedure[7].

Housing market indices are taken from Datastream (FTSE EPRA NAREIT or DJTM Real Estate; if none of them was available, DJTM Construction was adopted as a proxy for housing market). In case of the United States NAHB/Wells Fargo Housing Market Index (HMI) is applied.

Oil prices are represented by DJ UBS-Crude Oil Total Return Sub-Index.

The GVAR model in this paper resorts to both trade-based and financial weights for the purpose of construction of foreign-specific variables. Trade weights are computed from IMF's Direction of Trade Statistics quarterly data. Financial weights are derived from cross-country bank lending exposures data (also on quarterly basis) reported by BIS as a part of BIS Quarterly Review (tables 9B and 6A). The weights data run from December 1998 till March 2009. Calculation of mixed weights employs data from the Financial Structure Dataset of the World Bank as of January 2009. For the purpose of estimation mixed weights from the middle of the sample are put to use.

While conducting regional impulse response analysis, impulse response functions are aggregated according to weights based on yearly PPP data from Penn World Tables (1998 to 2007) for all countries under study.

Since the data in the model stretch over 10 years and include a number of developing economies which were subject to significant political, social and structural reforms, structural breaks are quite likely to be found in the time series. Even though the GVAR can accommodate co-breaking through the single-country $VARX^*$ submodels that may be more robust to the possibility of structural changes as compared to reduced form single equation models, the presence of structural instability in data could have a considerable impact on the parameters of the model. Therefore I perform several stability tests following Dees et al. (2007) and consider tests that are based on the residuals of the individual equations of the country-specific error correction models. To this account I include maximum OLS cumulative sum (CUSUM) statistic of Ploberger and Kraemer (1992) (denoted as PK sup) as well as its mean square version (PK msq), tests for parameter constancy against non-stationary alternatives proposed by Nyblom (1989) and, finally, sequential Wald type tests of a one-time structural change at an unknown change point. The latter tests include Quandt (1960) likelihood ratio statistic (QLR), the mean Wald statistic of Hansen (1992) and a test based on the exponential average proposed by Andrews and Ploberger (1994) (APW). In addition, heteroscedasticity-robust version of the above tests are reported.

Table C.17 presents results of the tests computed at the 5% significance level. Critical values are computed using bootstrap samples obtained from the GVAR model. The tests indicate a considerable evidence of structural instability in the data. In particular, equity

[7] See page http://www.census.gov/srd/www/x12a/ for more information.

prices and interest rates seem to undergo structural changes. However, when robust variant of the statistics are considered, it becomes apparent that the instability mainly affects error variances and its impact on the coefficient estimates is rather limited. In order to deal with the problem of unstable error variances I use robust standard errors when investigating the impact effects of foreign variables and impulse response functions.

3.3 Results

3.3.1 The mixed weights

The mixed weights are used to compute country-specific foreign variables x_{it}^* which represent both financial influence of a partner economy for a given country and a trade-based interlinkage between the two. In particular, foreign variables are specified as averages

$$x_{it}^* = \sum_{j=1}^{N} w_{ij} x_{jt} \tag{3.28}$$

where

$$w_{ii} = 0 \ , \qquad \text{and} \qquad \sum_{j=1}^{N} w_{ij} = 1 \ , \qquad \forall i = 1, 2, ..., N \tag{3.29}$$

Financial weights are calculated from the BIS data on bank lending exposures; trade weights are based on trade direction statistics of the IMF. The mixed weights are constructed in proportion to the relative size of the financial sector in the economy of the domestic country for a given time period. This size is measured according to following parameters of the financial structure disseminated by the World Bank:

- claims on domestic real non-financial sector by deposit money banks as a share of GDP,
- value of listed shares to GDP,
- private domestic debt securities issued by financial institutions and corporations as a share of GDP.

Aggregation weights for regions are based on averages of Purchasing Power Parity GDPs of all countries under study, for the period 1997 to 2007.

Due to addition of the financial weights, the mixed weights tend to be more volatile than their trade-based counterparts. When compared over time, linkage patterns reveal interesting integration characteristics, which are similar for both trade-based and financial weights.

Figures 3.1 and 3.2 reveal, with a notable exception of developed countries, a shift towards tighter links within economies from the same group. Emerging markets tend to gain on importance regardless of the origin of their partner economy. Frontier markets and

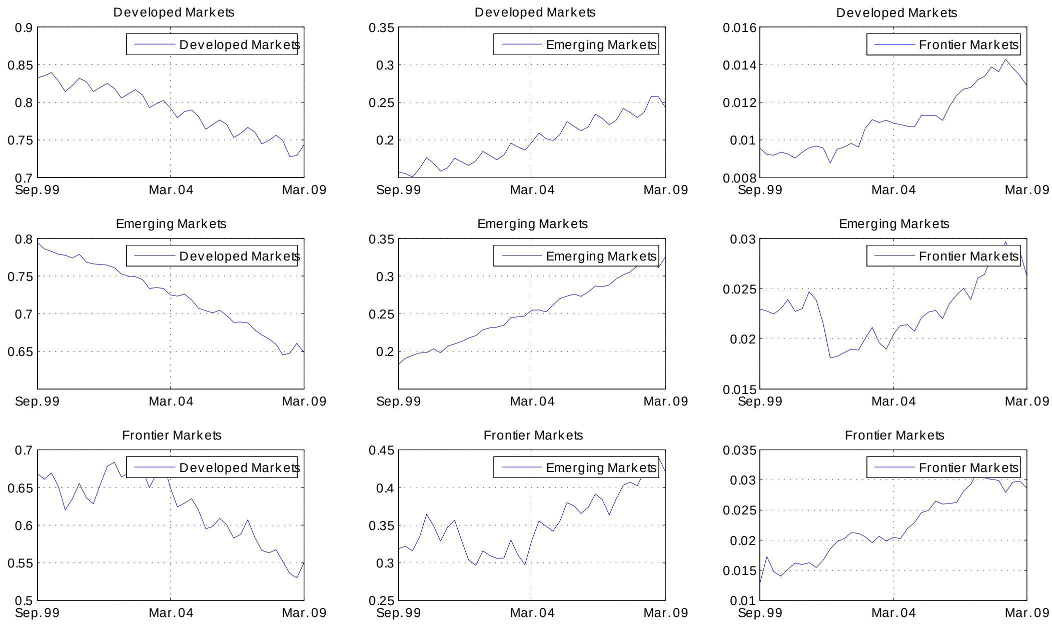

Figure 3.1: Direction of interdependencies over time, based on trade weights.

emerging economies seem to grow together whereas developed markets have a disposition to loosen the bonds among themselves. In addition, financial weights illustrate "flight to quality" in a slightly more pronounced way than the trade-based weights as the links to developed markets seem to have picked up a little bit lately, which suggest that developed economies tend to be a favoured financial partner at times of economic turmoil.

The trade-based weights show that the linkage between emerging markets has risen particularly strong. During the period under study the intra-group trade of emerging economies nearly doubled - from 18% in September 1999 to 33% in March 2009. At the same time emerging markets' trade with the developed countries declined from almost 80% to 65%. Similar proneness characterizes trade links of the frontier markets, yet with a significantly lower share of trade within this group itself. Overall, the trade statistics suggest that the centre of gravity for the flow of goods has been moving in the direction of emerging markets and, to a lesser extent, frontier markets.

The tendency observed in the structure of financial and trade-based weights leads in effect to results of Kose et al. (2008). The authors apply a dynamic factor model and identify a few common factors that drive fluctuations in macroeconomic aggregates on a global scale, within a group of countries and within all variables in one country. They find that the global and the country group specific factors account for a significant share of fluctuations in output, investment and consumption across countries. The biggest share is carried by industrial economies but the factor contributions are not equal - they tend to differ between variables. However, the authors observe a decrease in the average contribution of the global factor which supports the hypothesis of decoupling of economies. Contrary to the declining importance of the global factor, the group-specific factors tend to gain on importance. While confirming that the support for the global convergence weakens, Kose et al. (2008) find evidence for a higher degree of synchronization in business cycles within groups.

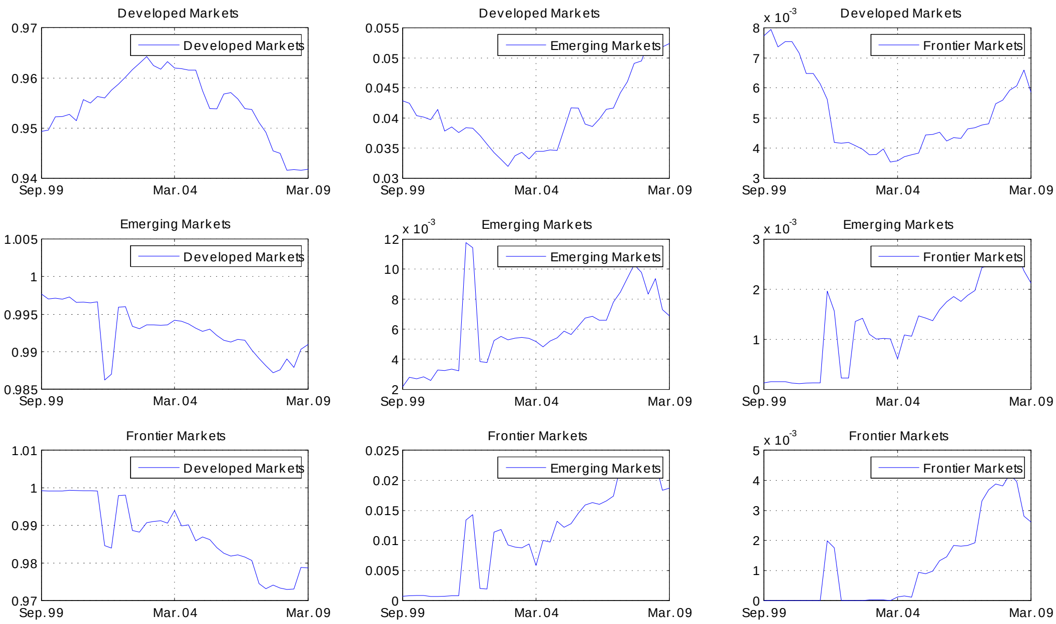

Figure 3.2: Direction of interdependencies over time, based on financial weights.

3.3.2 Integration properties of the model

The underlying assumption of the GVAR model estimation in this paper is that of the unitary order of integration for all variables included in the model. Tables C.3 and C.4 present results for augmented Dickey-Fuller GLS test proposed by Elliot et al. (1996). Not surprisingly, real equity prices, credit and interest rates tend to be unambiguously $I(1)$ processes. Furthermore, other variables also seem to be unit root processes; only in case of real housing prices for Russia the test statistic almost equalizes the critical value. This could be due to a poor quality of the data in case of Russian housing market. Sporadically, domestic variables in first differences turn out to be unit root processes as well. On the other hand, ADF-GLS tests for country-specific foreign variables deliver a clear picture of uniformly $I(1)$ processes.

3.3.3 Testing weak exogeneity

Another assumption of the model - weak exogeneity of the country-specific foreign variables x^*_{it} - can be tested by running first-difference regressions of the foreign variables and testing the joint significance of the country-specific error-correction terms in these regressions. This translates to conducting following regression for each element l of x^*_{it} and d_t in each country i

$$\Delta x^*_{it,l} = \mu_{il} + \sum_{j=1}^{r_i} \gamma_{ij,l} ECM^j_{it-1} + \phi_{i,l}\Delta x_{it-1} + \theta_{i,l}\Delta x^*_{it-1} + \delta_{i,l}\Delta d_{t-1} + \varepsilon_{it,l} \qquad (3.30)$$

where ECM^j_{it-1} are the estimated error-correction terms associated with the r_i cointegrating relations for the country i with $j = 1, ..., r_i$. The hypothesis of joint significance, $\gamma_{ij,l} = 0$, is verified by means of an F-test. Table C.5 reports results of that test.

Weak exogeneity is not rejected for most of the variables. And yet, for as many as 19 of them the F-test results in rejection of null hypothesis of weak exogeneity (19 out of 238 series, which represents 8% rejection rate). A notable case is Belgium, where test indicates that the oil price index is not weakly exogenous. Also, in case of Indonesia three out of five foreign variables (not counting oil) turn out to be endogenous; for Belgium, Brazil and Canada there are for each case two foreign variables for which null hypothesis of weak exogeneity is rejected at 5%. These results may suggest that in a model which aims at analysis of the global economy by including a large number of countries most or even all macroeconomic variables should be assumed to be endogenously determined. In fact, this assumption does not seem questionable in the wake of tightening trade and financial linkages among economies.

In general, given that only 8% of foreign variables do not satisfy the weak exogeneity assumption, I consider such an outcome tolerable and regard the estimation procedure of each country GVAR as admissible and justified.

3.3.4 Impact elasticities

Estimation of (3.21) produces estimates of coefficients of country-specific foreign variables in first differences. Those estimates, called impact elasticities, measure the contemporaneous effect of foreign variables on the domestic ones and show the extent of co-movement among variables across different countries. Table C.6 reports estimates of the impact elasticities.

Impact elasticities - when statistically significant - have a positive sign. The only exception from this rule is India's real credit to economy, indicating an inverse relationship between India's domestic supply of credit and its foreign counterpart. Elasticities for real output, equity prices and interest rates generally tend to be significant, with equity prices showing the greatest degree of contemporaneous interdependence, whereas real

GDP, credit and housing prices reveal a rather mixed pattern of statistical relevance.

In particular, the impact elasticities for equity prices are all positive and statistically significant for most of the countries. For over a third of them (17 countries), values are greater than one, i.e. they indicate that the domestic variable overreacts to a variation in real equity prices abroad. The opposite holds true for the remaining 23 countries for which impact elasticities are between zero and one. Group of economies where evidence of overreaction with respect to real equity prices is at hand includes eight developed countries and nine emerging economies. Overall, results for equity prices suggest a rather strong co-movement and synchronization across economies.

Most impact elasticities for the credit to economy are statistically not significant (except for nine economies). When being significant, they reveal in almost half of the case overshooting behavior of domestic variables with respect to variation in foreign aggregates, i.e. exactly the same behavior as observed for many equity series.

In case of real estate prices and short-term interest rate around half of the impact elasticities turn out not to be statistically meaningful. In addition, most of them are positive but below one, pointing at a very limited presence of overreaction patterns. Thus, there seems to be only a limited evidence of strong international linkages across countries concerning both variables.

Impact elasticities for GDP tend to be statistically significant (24 series) and positive. Values above one, which suggest overshooting of domestic real output to variation in foreign GDP, can be observed for Austria, Belgium, Greece, Ireland, Latvia, Malaysia, Slovak Republic, Slovenia, Spain and Sweden, i.e. small economies with an exception of Spain. Overall, the evidence of international linkages between economies with regard to real output seems to be somehow stronger than in the case of real credit and short-term interest rate.

When whole groups of countries are considered, it is difficult to formulate unequivocal statements about the characteristics of contemporaneous interdependence relationships resulting from the tests of weak exogeneity. Frontier markets seem to have a tendency towards overreaction of the real output provided that the estimates of impact elasticities are significant whereas the elasticity parameters associated with equity markets in those countries tend to be statistically irrelevant. Emerging markets overreact in equity prices but show almost no evidence of statistical significance of contemporaneous relationships between domestic and foreign variables for other macroeconomic aggregates. Developed countries, on the other hand, seem to be a very heterogenous group of economies both in terms of significance as well as magnitude of impact elasticities.

3.3.5 Generalized impulse responses

This paper examines the dynamics of the GVAR model by undertaking analysis of the Generalized Impulse Response Functions (GIRFs). In this application, three different shocks are simulated:

- a negative one standard error shock to the US real equity prices,
- a negative one standard error shock to the US real GDP,
- a positive one standard error shock to the US interest rate.

The scope of this simulation is to assess the extent of cross-boarder spillovers. Since economies are potentially linked to each other, this analysis should provide insights on how shocks propagate geographically and how different groups of economies react to them.

GIRFs, as proposed by Koop et al. (1996) and developed by Pesaran and Shin (1998) for vector error-correcting models, differ from Orthogonalized Impulse Response Functions (OIRFs) in that they do not orthogonalize residuals of the system but instead take historical correlations among variables into consideration, captured by the estimated variance-covariance matrix. Thus, contrary to OIRFs, GIRFs do not require any economic restrictions and they are invariant to the ordering of the variables in the system. To that end, GIRFs provide insight on how shocks propagate between countries and variables and unveil potential macroeconomic interdependence between economies. However, since the shocks are not identified, GIRFs do not supply information about the causal relationships among variables. Nevertheless, this disadvantage seems to be negligible compared to the difficulty of applying OIRFs in the GVAR context, since there is practically no reasonable and intuitive method to order many countries in the model.

Figures C.1 to C.3 present results for the GIRFs of the baseline setup, i.e. a model with mixed weights from the middle of the sample. In addition to graphs with confidence intervals at the 68 % significance level, calculated using sieve bootstrap technique with 1000 replications, figures without confidence bands, which are more comprehensible, are reported in the Appendix. When having taken the confidence intervals into account, most response functions seem not to be significantly different from zero. This fact may point at a low efficiency when estimating a model with many variables and too few monthly observations. However, it is still worthwhile to focus attention on the dynamic behavior of responses across all regions[8].

Overall, the evidence from the impulse response analysis points at a considerable degree of synchronization in co-movement of asset prices (equity and real estate markets) across economies. The dynamics of real activity, on the other hand, are characterized by some regional differences. Emerging and frontier markets appear to be more heterogeneous groups of countries than the industrial economies. The homogeneity of the developed markets may result from a high degree of financial and trade-based integration within this group.

[8]Bootstrap bands are derived from the global model in Equation (3.13) using the sieve procedure from Dees et al. (2007); applying bootstrap-after-bootstrap method of Kilian (1998) leads to even wider confidence bands. Tighter confidence bands could be obtained for the model with time-varying parameters, however, I could not simulate them due to computational limitations (simulations involve F matrix of dimension $(p \times (k \times N + 1)) \times (p \times (k \times N + 1)) \times t$, with p being maximum lag order of country-specific submodels and $t = 123$).

A negative shock to US equity

Figure C.5 shows evidence of an advanced synchronization in real equity prices among developed markets and emerging economies. Frontier markets' stock indices, on the other hand, repeat the same pattern of reaction to the US equity shock, but on a smaller scale. However, overall the performance pattern of equities seems to be quite similar in shape across all economies.

The impact of US equity market shock on total real credit to economy tends to be negative for all regions but it affects them in a different way. This decrease in credit can be interpreted as a result of contraction in net worth (equity) or as a signal of expected fall in output growth (falling GDP). While developed countries go through a relatively mild fall in credit, emerging markets witness a more pronounced decrease whereas frontier markets face even steeper a decline of the real credit. It is notable that on impact of the US equity market shock frontier markets respond by a relatively small decrease of equity prices and GDP but face the greatest slump in credit in the long run. This could perhaps indicate at the fact that a considerable part of credit growth in frontier economies is driven by foreign macroeconomic aggregates.

In case of the housing market both frontier economies and emerging markets tend to response to the US equity price shock through the same pattern of reaction as the developed markets do. The difference concerns the magnitude of reaction: emerging markets experience the most pronounced decrease of housing prices, developed markets' response is not significantly different from zero whereas frontier economies' response function lies somewhere between the others. Spread between emerging and frontier markets may in part be explained by a lower degree of development of the housing market in countries classified as frontier markets.

For the real GDP, an initial decline is followed by a subsequent recovery in case of the frontier economies only. The impact of shock to the US real equity prices results in persistent fall in output for both developed and emerging countries, with the latter overreacting in comparison to the former by a considerable amount. This outcome confirms the results of the analysis of impact elasticities.

Interest rates responses show a high degree of co-movement for all three groups of countries. Feedback of interest rates in emerging markets and frontier economies tends to be positive whereas a negative response can be observed for the developed markets. However, all responses tend to be marginal and insignificantly different from zero in the long run. Finally, negative shock to the US equity causes a persistent increase of the oil price.

Figures C.22 and C.23 from the Appendix present the same impulse response function for two different grouping methods: a more granular MSCI Barra classification and a grouping scheme from the IMF working paper of Galesi and Sgherri (2009) - shown in Tables C.14 and C.15, respectively. The aim of this short analysis is to capture possible heterogeneity in dynamic behavior within the groups of countries.

Following the negative US real equity shock, equity prices in sub-regions of emerging and frontier markets move quite similarly. On the other hand, equity prices in sub-regions of the developed markets reveal differences in responses; countries from the Pacific region tend to respond with only a slight decrease in real equity prices whereas USA and Canada react more markedly. The same is true for developed economies in case of housing markets and real credit, with the North American region reacting positively to the negative US equity shock but other developed countries not following the suit. Contrary to this, responses of the real GDP and short-term interest rate reveal more uniform behavior for all sub-regions of the developed countries. Developing markets (emerging and frontier economies), on the other hand, can be characterized by similar responses in equity prices and credit but a more nuanced reaction of short-term interest rates and real output. In particular, Brazil (GDP) and Argentina (interest rates and GDP) prove to be atypical members of their groups. To that end, striking differences between frontier markets Americas (Argentina) and frontier markets Central and Eastern Europe can be observed for impulse responses of the real output, housing markets and the short-term interest rate.

A negative shock to US GDP

Similarly to the effects of the previously considered disruption, equity prices across all regions tend to move in a very aligned way on the impact of US real GDP shock (Figure C.11). Frontier markets and emerging economies seem to overshoot in the short-run, when compared to the developed markets; frontier markets show a slightly more pronounced reaction of equity prices in the long run.

In addition, patterns of impulse response for equity prices and housing markets tend to coincide, with the latter moving a little bit less synchronized manner than the former. Overall, the shock to US real GDP gives rise to equity prices, presumably due to expected loosening of monetary policy; housing prices, on the other hand, increase because of lower loan costs which make housing more affordable and stimulate demand for it.

On the impact of the negative US GDP shock, interest rates fall in emerging economies and frontier markets (in the short-run), however, they increase in the developed markets. This development seems to conform with the response of GDP in the long-run, but it stands at odds when reaction of credit is considered. After the US output shock, all regions tend to stimulate economy by an influx of credit to the economy, with emerging markets as the forerunner. The most pronounced hike in credit results in the strongest recovery of GDP for emerging markets among all three regions - and this occurring after initial second worst setback. In addition, emerging and frontier markets appear to be more apt to lower their interest rates in response to possible economic contraction, probably because they have more scope for such moves due to having inherited a generally higher level of interest rates from past periods of high inflation. As in the case of the US equity price shock, negative shock to US GDP sparkles a persistent rise of the oil price.

Figures C.24 and C.25 illustrate impulse responses generated for the more granular classifications of regions. As mentioned before, emerging markets and frontier economies stand out as more heterogenous groups of countries. In particular, discrepancies between Brazil and Eastern Europe for emerging markets, and between Argentina and the frontier markets from the Eastern Europe catch one's eye. Developed markets, on the other hand, show more of uniform reaction patterns following a negative shock to the US real output.

A positive shock to US interest rate

As shown in Figure C.17, contractionary shock to US interest rate affects negatively real equity prices, housing markets and real GDP across all regions. Equity prices move along a similar pattern across all countries, with a bigger magnitude of the shift observed for emerging markets and frontier countries. In case of the real estate prices, emerging markets resemble developed economies more closely whereas frontier markets are characterized by a more distinct response to the positive US short-term interest rate shock.

On impact of the shock, real GDP in frontier markets plunges by a larger amount in the short run than its counterparts in other regions do, but it rebounds strongly afterwards and reaches the long-term level of impulse response of emerging economies after around 80 periods. Again, this outcome reconfirms broadly results of parameter tests for the impact elasticities. Credit markets reveal a strong synchronization and similarity of behavior between developed and emerging markets. Frontier markets, with a severe slump in the real credit after a positive US interest rate shock, constitute a notable outlier. Interest rates rise consistently across all regions. In developed markets and frontier economies they return to the pre-shock level after around 40 periods; a more significant reaction can be observed on the other hand for emerging markets where interest rates tend to permanently deviate from the initial level. Oil prices fall as increasing interest rates indicate slowing down of economic activity and expected fall in demand for this commodity.

As shown in Figures C.26 and C.27, equable patterns of responses following the negative US short-term interest rate shock can be observed across all sub-regions for real equity and the housing market. Credit, real output and interest rate, on the other hand, feature intra-regional heterogeneity. Most notable are the differences between American and European developing markets. In case of the developed markets, substantial discrepancies seem to emerge for the effects of the interest rate shock on the real GDP.

3.3.6 Generalized forecast error variance decomposition

Generalized forecast error variance decomposition (GFEVD) shows to what extent return variability in one aggregate or market can be explained by the innovations from other variables or markets in the VAR system. These relative contributions measure the importance of the innovation to a given region's or country's variable to the rest of the system and as such they can be considered as a useful device to study propagation of shocks between regions. Results of this analysis for a one standard error shock to the US equity are reported in Tables C.8, C.9 and C.10. As sums of the contributions of innovations do however not sum up to one due to existence of contemporaneous correlations between shocks, they must be adjusted accordingly.

GFEVD data point at quite different dynamic behavior of variables across regions. Following US equity shock, is can be observed that, among developed markets' variables, real equity prices explain most of the forecast error variance in the short run. In the European developed markets this effect continues to hold in the long run as well and it spills over to GDP. Among developed markets, the European countries tend to have the most variation, with contribution to variance of a historical shock that increases steadily across all macroeconomic and financial aggregates. In case of Pacific developed markets the relative contribution to the forecast variance appears to be evenly spread between all variables, with a somehow stronger emphasis on the aggregate credit.

Emerging markets present a fairly different picture of behavior. Here, in the short term, variability seems to be driven mostly by real credit and interest rates. After two months real equity prices gain on importance and tend to explain a major share of the variance of the shock. In case of frontier markets equity prices contribute mostly to the explanation of the forecast variance; real output tends to play an important role in the short run whereas real credit and housing market build up their relevance in the long run.

A negative shock to US real GDP results in an evenly spread variation between American and European developed markets in the short run. However, as time passes on, the variability moves away from the American economies towards the European industrial countries. For the American markets, the most variance is concentrated on output; in case of the European counterparts, the innovation to US GDP tends to influence all macroeconomic aggregates proportionally and its impact on equity markets rises considerably in the long run. Pacific developed markets, on the other hand, seem to be detached from the impact of shocks in US real GDP.

Following the perturbation in the US GDP, the variability in aggregates from the emerging markets reaches similar levels as in the case of equity shock. In the first few months, the impact is most perceptible for output whereas in the long run more variability emerges in equity prices and interest rate. When compared to the equity shock, Asian emerging markets and frontier markets tend to show less sensitivity to innovations in the US GDP in the short run; in the long run, however, the spillover effect becomes more pronounced.

GFEVD data for a positive shock in US interest rate reveal the weakest spillovers across economies. In particular, the share of variance for the macroeconomic aggregates from emerging and frontier markets tends to be substantially below the levels observed for previous innovations. Almost 80 per cent of the variance following the shock stays in the short run within the developed markets; as before, the innovation contributes primarily to the variability in European aggregates, in particular interest rates and equity prices. The variance for the American industrial countries decays gradually whereas the effects induced by the US interest rate shock in the European developed markets intensify and then level off at around 50 per cent.

As with respect to interregional linkages, results of forecast error variance decomposition reveal the essential share of foreign regions in contribution to the variance of the shock to US equity. Initially, as much as 85 per cent of the variance can be related to foreign variables, with the European developed markets usually being the dominant contributor. In addition, there is a lot of evidence of substantial spillovers between different macroeconomic aggregates within European industrial economies, with equity markets, interest rate and output playing the most important roles. On the impact US shocks, share of the emerging and frontier economies tends to be stable at around 38 per cent and displays some intra-regional shifts in proportion of contribution to the variance of the shock over time. In case of Asian emerging markets, US shocks seem not to contribute significantly to innovations in any of the macroeconomic variables of the region at all.

3.4 Counterfactual analysis

GVAR system presented in this paper utilizes foreign country-specific weakly exogenous variables in modeling the linkage between economies. These variables are calculated from the data using mixed weights derived from trade-based and financial international flows. Since the weights are supposed to capture spillovers between countries and regions and to measure the degree of international interdependence, they will influence the outcome of the model: parameters, number of cointegrating relations and dynamic aspects of the GVAR system. Therefore, in order to explore both the impact of the weighting scheme and the sensitivity of the GVAR with respect to the definition of foreign variables I conduct an analysis in which different weight arrangements come into play. First, I generate GIRFs using mixed weights from the beginning (average of 1998-1999) and the end of the sample (average of 2008-2009) and compare them the baseline scenario for GIRFs with mixed weights from the middle of the sample. Second, I consider making use of trade-based weights only in order to capture the extent to which financial weights matter for the international interdependencies. Third, by shutting down transmission channels related to different foreign variables I examine the importance of distinct transmission channels for interregional spillovers. All figures are presented in Appendix.

3.4.1 Mixed weights

Figures C.4 and C.6 show impulse responses to the negative on standard error shock to US equity - for a model version with mixed weights taken from the beginning and from the end of the sample, respectively. When compared to the baseline case, two observations can be made. First, beginning of the sample weights tend to introduce a sinusoid shape into the GIRFs, as data for financial weights in the beginning is either more scarce or it underlines weaker financial integration among some groups of countries. However, impulse response functions generally retain the characteristics of reaction patterns which can be observed for all variables when mixed weights from the middle of the sample are used.

Second, weights from the end of the sample highlight more pronounced co-movement of regions in response to the US equity shock. In particular, it can observed that following the US equity shock real credit and housing market of emerging and frontier markets pool together whereas in case of real GDP it is developed markets and emerging countries that share quite a similar response to the shock. Also, end of the sample weights lead to a long-run recovery in equity prices, contrary to impulse responses generated for the model with other weighting schemes.

As shown in Figures C.10 and C.12, using different points in time for the calculation of weights has a similar impact on GIRFs when the propagation of a negative US GDP shock is considered. Mixed weights from the beginning of the sample result in a wave-like reaction patterns whereas end of the sample weights emphasize persistence and cointegration among macroeconomic aggregates across the regions. Strikingly, both weighting schemes, when applied to the model, lead to completely different conclusions about the impact of the shock to US real output. Based on the weights from the late 1990s all variables respond in an almost unanimous and negative way; end of the sample weights, on the other hand, produce overwhelmingly positive impulse responses; in particular, real GDP falls in the short run across all regions but it rises in the long-term.

Impact of a negative one standard error shock to US interest rate results in more likewise impulse responses regardless of timing of the mixed weights (Figures C.16 and C.18). It can be observed that using recent weights generates the most erratic feedback of all variables in terms of the magnitude of reaction to the shock. In particular, a drawdown following the negative one standard error US interest rate shock tends to be around three times as large as a drawdown in impulse responses estimated with weights from the middle of the sample.

In general, weighting scheme seems to considerably affect the dynamic results of the GVAR system. Since weights capture temporal interdependencies across regions, they impact the number of cointegrating relations (see Table C.7 in Appendix) as well as shape, direction, persistence and variation of the feedback following the shocks simulated in the model. Depending on the source of innovation, choosing a particular point in time in order to determine weights may lead to contradictory statements about the system dynamics.

3.4.2 Financial weights

Mixed weights used in this paper are supposed to reflect both trade-based and financial linkages between countries and regions. Given increasing global integration they take into account both flow of goods and money as transmission channels of spillover across economies. Therefore, it is worthwhile to examine the impact of this duality by studying dynamics of a GVAR system with foreign country-specific variables calculated using trade-based weights only.

Figures C.7 to C.9 present GIRFs for a negative one standard error shock to US equity. It can be noticed that compared to mixed weights impulse responses are larger in scale. In case of equity prices, housing market and GDP feedback to the shock indicates a stronger interrelation and similarity of reaction across regions. In addition, responses of frontier markets' real credit and GDP overshoot substantially in contrast to mixed weights. Finally, reaction of the oil price becomes transient when trade-based weights from the middle of the sample are concerned.

In case of a negative one standard deviation shock to the US GDP, employing trade-based weights does not change the magnitude of impulse responses significantly. The dynamics of GIRFs stay generally in line with responses generated in the baseline scenario, with a couple of exceptions constituted by reactions of GDP and credit to the shock. It can be observed that using trade-based weights from the beginning of the sample in the model generates persistently decreasing GDP across all regions. As shown in Figures C.13 to C.15, this pattern of reaction changes over time; depending on the timing of weights response of real output for all regions varies between a persistent decrease and a gradual increase after 10 to 20 periods following the negative shock to US GDP. Also, impulse response patterns for real credit in frontier markets seem to evolve over time. Additionally, both credit and GDP in frontier markets tend to resemble their counterparts from other groups of economies in terms of dynamic behavior when trade-based weights from the end of the sample are taken into consideration.

A negative one standard deviation shock to US short-term interest rate in the model with trade-based weights generates GIRFs which are quite similar to those for the version of the model with mixed weights (see Figures C.19 to C.21 in Appendix). Dispensing financial flows from the calculation of weights does not seem to have any substantial effect on the behavior of variables. However, utilizing trade-based weighting scheme leads to rising interrelation of responses of equity prices and GDP across the regions. In addition, as more up-to-date weights are used, the range of reaction for all variables increases considerably.

In addition to the impulse response analysis, I compare the impact of shocks for models with different weighting schemes using the forecast error variance decomposition. As shown in Figures C.4 to C.9, following results can be observed. First of all, financial weights alter the patterns of spillovers markedly. For instance, in case of the US equity shock, deploying mixed weights in the model results in a considerable amount of variability to move abroad from equity markets in the American industrial economies to equities in the European developed markets. It also results in a more instantaneous response of emerging economies to shocks whereas the transmission channel using trade weights takes more time to carry the impact from the developed to emerging markets. On the other hand, financial interrelations seem to transport less of the impact of US innovations to the emerging and frontier economies when GDP and interest rate shocks are concerned. However, over time financial linkages tend to bring about an increase in share of the emerging and frontier markets in the overall variation of macroeconomic aggregates following shocks originating in the US. In particular, they increase the variance of equities and real estate markets across the developing countries. In case of industrial economies, financial interconnections result in a growing persistence in the variation of economic variables.

To sum up, employing a measure of financial interdependence between countries along with a trade-based measure for the purpose of weights' construction seems to results in a notable change of the dynamics for some of the variables in the GVAR system. In most cases, enriching trade-based weights with data coming from financial links leads to evidence of diluted interrelations between macroeconomic variables across regions. Impulse responses in a model with mixed weights tend to be more moderate in scale. Such results may indicate at a fact that financial linkages add yet another dimension of interdependencies between economies that make transmission mechanism of shocks more subtle and complex. On the other hand, it is also possible that cross-country bank lending exposures data capture the financial interrelationship across regions and economies only to a certain degree. GVAR model is set to overcome the dimensionality problem faced often in macroeconomic empirical applications by modeling links between countries through foreign variables calculated as averages of macroeconomic aggregates of the partner economies. Yet this advantage seems to come at a cost of considerable dependence on the method which is employed to calculate foreign variables.

3.4.3 Shutdown of transmission channels

Shutdown of transmission channels involves muting one channel at a time and comparing the impulse response generated from this scenario with the baseline case where all channels are operating. This approach amounts therefore to setting to zero columns in matrices from Equation (3.1) that correspond to foreign variables being muted. The result indicates the strength of a particular transmission channel in propagation of shocks across borders. Figures C.28 to C.30 present the impulse responses functions generated by switching off foreign equity markets, foreign GDP and the foreign short-term interest rate.

The findings indicate that equity prices constitute an important transmission channel of spillovers across regions. They tend to amplify the effects of shocks; this result manifests itself most notably in the case of interest rate shocks. Spillovers through international equity prices seem to affect domestic equity markets, real estate prices and GDP whereas the impact on real credit and interest rate is more curbed. The evidence for international interest rates, on the other hand, points at a very limited role as a transmission channels of shocks between economies. In particular, impulse response functions generated with the muted interest rate channel virtually do not differ from the responses in the baseline scenario when US equity or interest rate shocks are considered. The results for transmission of innovations through foreign GDP suggest a more distinguished role when compared to the interest rates; however, the GDP channel tends to produce smaller effects than the transmission channel of foreign equity prices. Spillovers affected by changes in foreign output seem to mostly influence domestic GDP, real credit to economy and domestic equity markets. Overall, the results from shutting down various channels of shock transmission between economies accentuate the prominence of equity markets, which amplify responses to shocks across all regions and affect most domestic variables. Foreign output is less important but its impact is still considerable; foreign interest rates play no significant role in transmission of shocks across borders.

3.5 Time-varying weights

Given the importance of weighting scheme on the parameter estimates and the dynamics of GVAR I construct a model for weights that allows to capture its dynamic characteristics and incorporate them into the GVAR system so that feedback from macroeconomic variables to weights (and back from weights to macroeconomic aggregates through country-specific foreign variables) is facilitated and explored. A time-varying version of the weights matrix in Equation (3.8), W_{it}, consists of weights $w_{ij,t}$ representing a share of country i in the total interconnection of country j with the outside world, measured in terms of trade, financial flows or some combination thereof. In case of trade-based weights, $w_{ij,t}$ measures a relative size of imports and exports between country i and j over the total sum of imports and exports of country j at time t:

$$w_{ij,t} = \frac{flow_{ij,t} + flow_{ji,t}}{\sum_{i=1}^{N} flow_{ij,t} + \sum_{j=1}^{N} flow_{ij,t}} \tag{3.31}$$

where $flow_{ij,t}$ represents a trade-based flow of goods from i to j at t.

Therefore, modeling weights can be accomplished by deploying a model for the underlying trade-based flows. In order to allow for feedback from the macroeconomic variables in the GVAR model but simultaneously keep the sub-model for weights parsimonious I utilize an autoregressive distributed lag setup $ARDL\,(p, q_1, q_2)$:

$$flow_{ij,t} = a_0 + \sum_{k=1}^{p} \Theta_k flow_{ij,t-k} + \sum_{n=0}^{q_1} \Phi_n gdp_{i,t-n} + \sum_{m=0}^{q_2} \Psi_m gdp_{j,t-m} + \varepsilon_{ij,t} \tag{3.32}$$

Thus, in case of $ARDL\,(1,1,1)$ estimation of all $w_{ij,t}$ terms translates to running $N \times (N-1)$ OLS regressions from Equation (3.32), each of the following form:

$$\begin{aligned} \Delta flow_{ij,t} \quad = \quad & a_0 + (\Theta_1 - 1)\, flow_{ij,t-1} + (\Phi_0 + \Phi_1)\, gdp_{i,t-1} + (\Psi_0 + \Psi_1)\, gdp_{j,t-1} \\ & + \Phi_0 \Delta gdp_{i,t} + \Psi_0 \Delta gdp_{j,t} + \varepsilon_{ij,t} \end{aligned} \tag{3.33}$$

where terms in first differences account for contemporaneous impact of innovations in real output on the trade dynamics. Now, rewriting Equation (3.8) as $z_{it} = W_{it} x_t$ leads to a GVAR model in Equation (3.10) with time-varying parameters:

$$G_t x_t = a_0 + a_1 + H_{t-1} x_{t-1} + \Psi_0 d_t + \Psi_1 d_{t-1} + \varepsilon_t \tag{3.34}$$

Provided that G_t matrix is not singular for all t, the GVAR(1) system can be written as:

$$x_t = b_{0t} + b_{1t} + F_t x_{t-1} + \Upsilon_{0t} d_t + \Upsilon_{1t} d_{t-1} + u_t \tag{3.35}$$

where $F_t = G_t^{-1} H_{t-1}$ and all other parameters are defined in analogy to Equation (3.13) as:

$$b_{0t} = G_t^{-1} a_0 \ , \quad b_{1t} = G_t^{-1} a_1 \ , \quad \Upsilon_{0t} = G_t^{-1} \Psi_0 \ , \quad \Upsilon_{1t} = G_t^{-1} \Psi_1 \ , \quad u_t = G_t^{-1} \varepsilon_t \tag{3.36}$$

To illustrate this approach I estimate a three-country GVAR model for China, Germany and the USA. I use the set of variables from Equations (3.25) and (3.27) together with time-varying trade-based weights. Table C.18 in Appendix reports statistics for error-correcting terms and long-run coefficients equation of all six ARDL regressions. Figures 3.3 and 3.4 show impulse responses to a negative one standard deviation in US GDP for this model: red line depicts impulse response functions calculated with forecasted weights whereas blue line represents impulse responses with weights fixed at the time when the GDP shock takes place.

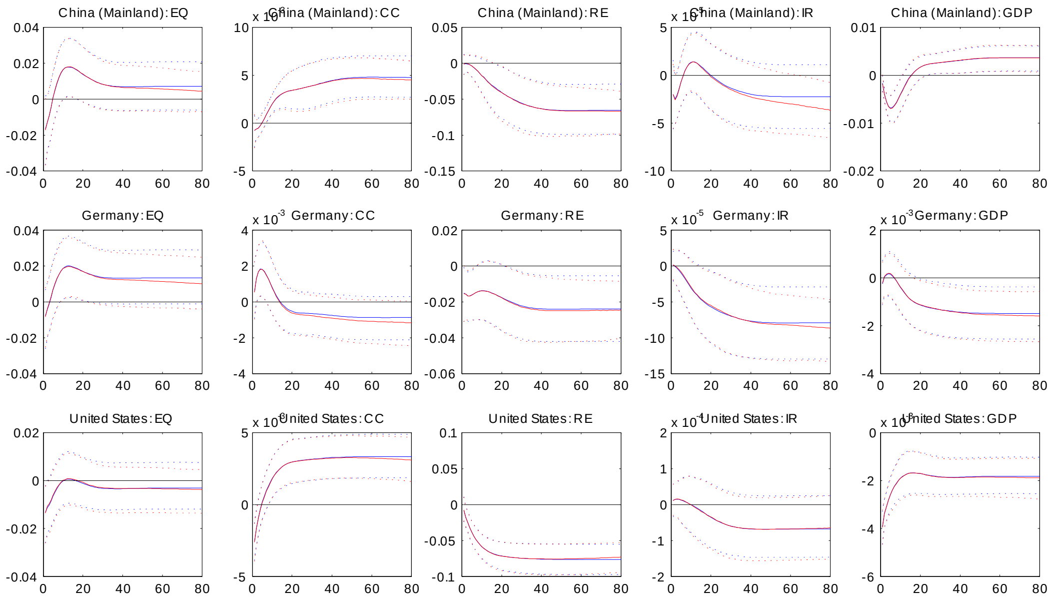

Figure 3.3: Impulse responses to a negative one standard error shock to US GDP with 95% confidence bands.

As shown in Figure 3.3 differences between impulse response functions with fixed and time-varying weights are marginal. All responses lie within each other's 95% confidence bands, most of them are significantly different from zero at the 5% level. A negative one standard deviation shock to US GDP leads to fairly similar reactions of real equity prices and housing markets among the three economies. On the other hand, responses of real credit, short-term interest rates and GDP aggregates differ; China and the USA respond to contraction in the US GDP by a significant increase of credit supply but their adjustments in interest rates tend to be insignificant. Germany, on the other hand, lowers considerably its short-term interest rate in the long run. Of all three economies, China's output tends to expand after around 20 months.

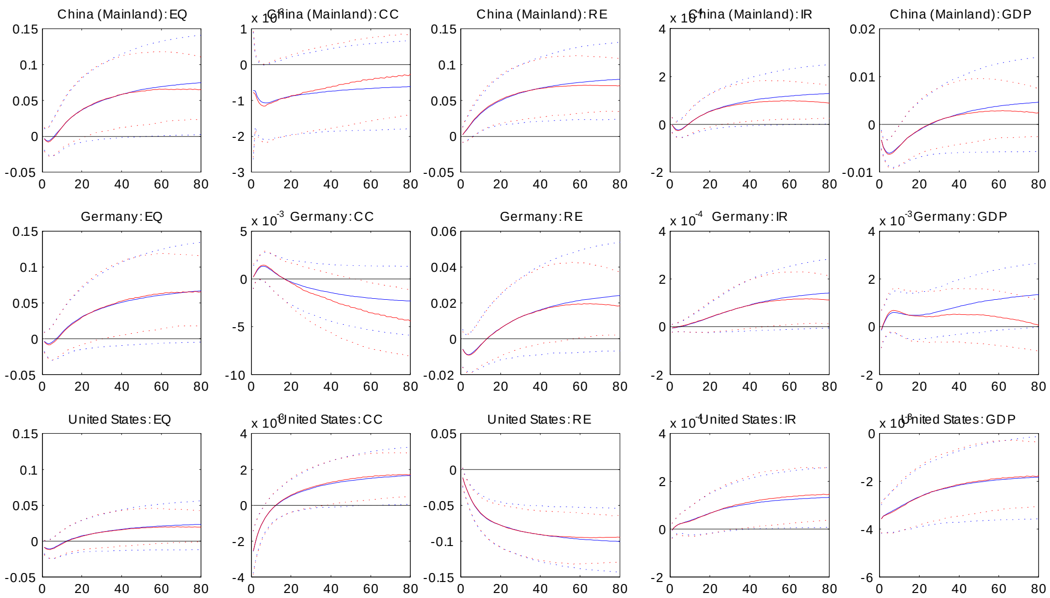

Figure 3.4: Impulse responses to a negative one standard error shock to US GDP with 95% confidence bands.

Figure 3.4 reconsiders impulse response functions to the very same shock but estimated for a model with data sample ending in November 2007, i.e. before the recent financial crisis set out. Omitting financial crisis in estimation tends magnifies the differences between impulse responses derived using constant and projected weights.

3.6 Conclusion

This paper uses GVAR model to address the issue of regional interdependencies and synchronization of business cycles between economies. It utilizes both financial and trade-based weights to analyse transmission mechanism of real and financial shocks across borders. The paper includes a considerable number of economies and employs key macroeconomic and financial aggregates in the analysis. In addition, the model with time-varying parameters is developed which accounts for feedback between macroeconomic variables and weights that capture interrelationships among countries.

Regional spillovers between developed, emerging and frontier economies are examined by means of the analysis of parameter estimates for the impact elasticities, impulse response functions and forecast error variance decomposition. The findings of this paper suggest that the development in international financial markets and cross-border trade activity seem to expand the transmission of shocks abroad and to amplify business cycle fluctuations to regions where the integration is greater, especially as a result of asset price movements. Impulse responses of real sectors tend to mildly support the idea of decoupling of economies, showing evidence of slightly different paths of economic performance across regions.

Impact elasticity estimates from the model presented in this paper suggest strong international interrelation of equity prices. Credit aggregates, real estate prices and short-term seem to be more decoupled across regions, and so does real GDP, too. These results are sensitive with respect to the size of economy; frontier markets and small developed countries tend to overshoot in the feedback of the real output to external shocks. Emerging markets overreact in equity prices but show almost no evidence of statistical significance of contemporaneous relationships between domestic and foreign variables for other macroeconomic aggregates. As GIRFs and GFEVDs indicate, equity prices and housing markets are strongly interrelated both across regions and with groups of countries. Yet significant differences within groups can be found for other macroeconomic aggregates, including credit, interest rates and GDP. Using mixed weights proves to be useful in documenting changes in the relationship between countries and regions. For instance, in accordance with the globalization hypothesis, moving away from distant to recent weights suggests more synchronized responses to shocks across regions. Financial linkages matter, however, financial weights tend to substantially alter the dynamics of the GVAR system by adding moderation and, to some extent, more disattachement among regions. As more countries join the single global market, new linkage constellations and spillover patterns emerge between economies. Contrary to the convergence hypothesis, rising trade-based and financial linkages seem to partly endorse group-specific business cycles.

These results are only as reliable as the model used to derive them proves to be. The outcome of cointegration and weak exogeneity tests as well as the results of Monte Carlo experiments suggest problems with endogeneity of foreign variables and poor size property of the cointegration statistics for systems with unit root processes.

Bibliography

Abel, A., B. Bernanke, 2001, Macro Economics, 4th Edition. Addison Wesley Longman, Inc.

Acharya, V., H. Naqvi, 2010, The seeds of a crisis: a theory of bank liquidity and risk taking over the business cycle, AFA 2011 Denver Meetings Paper.

Adrian, T., E. Moench, H. S. Shin, 2010, Financial intermediation, asset prices, and the macroeconomic dynamics, Federal Reserve Bank of New York, Staff Report No. 422.

Akin, C., M.A. Kose, 2008, Changing the nature of North-South linkages: stylized facts and explanations, Journal of Asian Economics, 19, 1-28.

Allen, F., E. Carletti, D. Gale, 2009, Interbank market liquidity and central bank intervention, Journal of Monetary Economics, 56(5), 649-652.

Andrews, D.W.K., W. Ploberger, 1994, Optimal tests when a nuisance parameter is present only under the alternative, Econometrica, 62, 1383-1414.

Ang, A., M. Piazzesi, 2003, A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables, Journal of Monetary Economics, 50, 745-787.

Ang, A., M. Piazzesi, M. Wei, 2006, What does the yield curve tell us about GDP growth?, Journal of Econometrics, 131, 359-403.

Angeloni, I., E. Faia, 2010, Capital regulation and monetary policy with fragile banks, Working paper.

Assenmacher-Wesche, A., M.H. Pesaran, 2008, A VECX* model of the Swiss economy, Working paper.

Backus, D.K., S. Foresi, C.I. Telmer, 2001, Affine term structure models and the forward premium anomaly, Journal of Finance, 51, 279-304.

Basel Committee on Banking Supervision, 2009, Strengthening the Resilience of the Banking Sector.

Basel Committee on Banking Supervision, 2009, The de Larosière Group Report.

Beenstock, M., J.A. Longbottom, 1981, The term structure of interest rates in a small open economy, Journal of Money, Credit and Banking, 13(1), 44-59.

Bekaert, G., R.J. Hodrick, 2001, Expectations hypotheses tests, The Journal of Finance, 66(4), 1357-1394.

Bernanke, B. S., M. Gertler, S. Gilchrist, 1999, The financial accelerator in a quantitative business cycle framework, Handbook of Macroeconomics, Amsterdam: North Holland.

Bernanke, B. S., V. R. Reinhart, 2004, Conducting monetary policy at very low short-term interest rates, The American Economic Review, 94(2), 85-96.

Binder, M., Q. Chen, X. Zhang, 2010, On the effects of monetary policy shocks on exchange rates, CESifo Working Paper Series No. 3162.

Brandt, M.W., J.H. Cochrane, P. Santa-Clara, 2006, International risk sharing is better than you think, or exchange rates are too smooth, Journal of Monetary Economics, 53, 671–698.

Buiter, W. H, N. Panigirtzoglou, 1999, Liquidity traps: how to avoid them and how to escape them, CEPR Discussion Papers 2203, C.E.P.R. Discussion Papers.

Bussiere, M., A. Chudik, G. Sestieri, 2009, Modelling global trade flows. Results from a GVAR model. ECB Working Paper Series, No. 1087.

Campbell, J.Y., R.J. Shiller, 1991, Yield spreads and interest rate movements: a bird's eye view, Review of Economic Studies, 58, 495-514.

Chow, A.L., G.C. Lin, 1971, Best linear unbiased interpolation, distribution, and extrapolation of time series by related series, Review of Economics and Statistics, 53(4), 372-375.

Chow, A.L., G.C. Lin, 1976, Best linear unbiased estimation of missing observations in an economic time series, Journal of American Statistical Association, 71, 719-721.

Christensen, J.H.E., F.X. Diebold, G.D. Rudebusch, 2007, The affine arbitrage-free class of Nelson-Siegel term structure models, NBER Working Paper Series, No. 13611.

Christensen, J.H.E., F.X. Diebold, G.D. Rudebusch, 2008, An arbitrage-free generalized Nelson-Siegel term structure model, NBER Working Paper Series, No. 14463.

Christiano, L., R. Motto, M. Rostagno, 2010, Financial factors in economic fluctuations, ECB Working Paper Series, No. 1192.

Christiansen, I., A. Dib, 2008, The financial accelerator in an estimated New Keynesian model, Review of Economic Dynamics, 11(1), 155-178.

Chudik, A., M.H. Pesaran, 2009, Infinite-dimensional VARs and factor models, ECB Working Paper Series, No. 998.

Chudik, A., M.H. Pesaran, E. Tosetti, 2009, Weak and strong cross section dependence and estimation of large panels, ECB Working Paper Series, No. 1100.

Clarida, R., J. Gali, M. Gertler, 1999, The science of monetary policy: a new Keynesian perspective, Journal of Economic Perspectives, 37(4), 1661-1707.

Clarida, R., J. Galí, M. Gertler, 2000, Monetary policy rules and macroeconomic stability: evidence and some theory, Quarterly Journal of Economics, 115(1), 147-180.

Covas, F., S. Fujita, 2009, Time-varying requirements in a general equilibrium model of liquidity dependence, Philadelphia Fed Working paper 09-23.

Curdia, V., M. Woodford, 2010, The central-bank balance sheet as an instrument of monetary policy, Journal of Monetary Economics, forthcoming.

Dai, Q., K.J. Singleton, 2000, Specification analysis of affine term structure models, Journal of Finance, 55, 1943-1978.

Dai, Q., K.J. Singleton, 2002, Expectation puzzles, time-varying risk premia, and affine models of the term structure, Journal of Financial Economics, 63, 415-441.

de Walque, G., O. Pierrard, A. Rouabah, 2009, Financial (in)stability, supervision and liquidity injections: a dynamic general equilibrium approach, C.E.P.R. Discussion Paper No. 7202.

Dees, S., F. di Mauro, M.H. Pesaran, L.V. Smith, 2007, Exploring the international linkages of the Euro Area: a global VAR analysis, Journal of Applied Econometrics, 22, 1-38.

Dees, S., A. Saint-Guilheim, 2009, The role of the United States in the global economy and its evolution over time, ECB Working Paper Series, No. 1034.

Derracq Pariès, M., C. K. Sørensen, D. R. Palenzuela, 2010, Macroeconomic propagation under different regulatory regimes: evidence from an estimated DSGE model for the euro area, ECB Working Paper Series, No. 1251.

Dewachter, H., K. Maes, 2001, An admissible affine model for joint term structure dynamics of interest rates, Mimeo, University of Leuven.

Dewachter, H., M. Lyrio, 2006, Macro Factors and the term structure of interest rates, Journal of Money, Credit, and Banking, 38(1), 119-140.

Dib, A., 2010, Banks, credit market frictions and business cycles, Bank of Canada, Working Paper No. 2010-24.

Diebold, F.X., C. Li, 2006, Forecasting the term structure of government bond yields, Journal of Econometrics, 130, 337-364.

Diebold, F.X., G.D. Rudebusch, S.B. Aruoba, 2006, The macroeconomy and the yield curve: a dynamic latent factor approach, Journal of Econometrics, 131, 309-338.

Diez de los Rios, A., 2009, Can affine term structure models help us predict exchange rates?, Journal of Money, Credit and Banking, 41(4), 755-766.

Doyle, B., J. Faust, 2005, Breaks in the variability and comovement of G-7 economic growth, Review of Economics and Statistics, 87(4), 721–740.

Duffee, G.R., 2002, Term premia and interest rate forecasts in affine models, Journal of Finance, 57(1), 405-443.

Duffie, D., R. Kan, 1996, A yield-factor model of interest rates, Mathematical Finance, 6, 379-406.

Dungey, M., R. Fry, 2009, The identification of fiscal and monetary policy in a structural VAR, Economic Modelling, 26, 1147-1160.

Elliot, G., T.J. Rothenberg, J.H. Stock, 1996, Efficient tests for an autoregressive unit root, Econometrica, 64, 813-836.

Engle, R.F., D.F. Hendry, J.F. Richard, 1983, Exogeneity, Econometrica, 51, 277-304.

Erceg, C.J., L. Guerrieri, C. Gust, 2005, SIGMA: A New Open Economy Model for Policy Analysis, Board of Governors of the Federal Reserve System, International Finance Discussion Papers, N. 835.

Ewerhart, C., J. Tapking, 2008, Repo markets, counterparty risk and the 2007/2008 liquidity crisis, ECB Working Paper Series, No. 909.

Faia, E., T. Monacelli, 2007, Optimal monetary policy rules, asset prices and credit frictions, Journal of Economic Dynamics and Control, 31(10), 3228-3254.

Fama, F., 1984, Forward and spot exchange rates, Journal of Monetary Economics, 14, 319-338.

Fisher, W.H., 2000, The term structure of interest rates in a small open economy: a stochastic analysis, Open Economies Review, 11, 261–278.

Freixas, X., J. Jorge, 2008, The role of interbank markets in monetary policy: a model with credit rationing, Journal of Money, Credit and Banking, 40(6), 1151-1176.

Galesi, A., S. Sgherri, 2009, Regional financial spillovers across Europe: a global VAR analysis, IMF Working Paper, WP/09/23.

Gali, J., M. Gertler, 2007, Macroeconomic modeling for monetary policy evaluation, Journal of Economic Perspectives, 21(4), 25-46.

Garratt, A., K. Lee, M.H. Pesaran, Y. Shin, 2006, Global and national macroeconometric modelling: a long-run structural approach, Oxford University Press.

Gerali, A., S. Neri, L. Sessa, F. M. Signoretti, 2010, Credit and banking in a DSGE model of the Euro Area, Banca d'Italia, Working paper No.741.

Gerlach, S., F. Smets, 1997, The term structure of Euro-rates: some evidence in support of the expectations hypothesis, Journal of International Money and Finance, 16(2), 305-321.

Gertler, M., N. Kiyotaki, 2010, Financial intermediation and credit policy in business cycle analysis, Working paper.

Gertler, M., P. Karadi, 2009, A model of unconventional monetary policy, NYU, Working paper.

Goodfriend, M., 2000, Overcoming the Zero Bound on Interest Rate Policy, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 32(4), 1007-35.

Goodfriend, M., B. McCallum, 2007, Banking and interest rates in monetary policy analysis: a quantitative exploration, Journal of Monetary Economics, 54(5), 1480-1507.

Goodhart, C., P. Sunirand, D. Tsomocos, 2005, A risk assessment model for banks, Annalys of Finance, 1(2), 197-224.

Goodhart, C., P. Sunirand, D. Tsomocos, 2006, A model to analyse financial fragility, Economic Theory, 27, 3885-3900.

Granger, C.W.J., J.L. Lin, 1995, Causality in the long run, Econometric Theory, 11(3), 530-536.

Hansen, B.E., 1992, Tests for parameter instability in regressions with I(1) processes, Journal of Business and Economic Statistics, 10(3), 321-335.

Hardouvelis, G.A., 1994, The term structure spread and future changes in long and short rates in the G7 countries. Is there a puzzle? Journal of Monetary Economics, 33, 255-283.

He, Z., A. Krishnamurthy, 2009, A model of capital and crises, Working paper.

Heathcote, J. , F. Perri, 2004, Financial globalization and real regionalization, Journal of Economic Theory, 119(1), 207–243.

Helbing, T., P. Berezin, M.A. Kose, M. Kumhof, D. Laxton, N. Spatafora, 2007, Decoupling the train? Spillovers and cycles in the global economy, World Economic Outlook (April 2007), 121-160.

Helbling, T., T. Bayoumi, 2003, Are they all in the same boat? The 2000-2001 growth slowdown and the G-7 business cycle linkages, IMF Working Paper, WP/03/46.

Hiebert, P., I. Vansteenkiste, 2007, International trade, technological shocks and spillovers in the labour market; A GVAR analysis of the US manufacturing sector, ECB Working Paper Series, No. 731.

Hildebrand, P., 2008, Is Basel II Enough? The Benefits of a Leverage Ratio, Financial Markets Group Lecture, London School of Economics.

Holmstrom B., J. Tirole, 1997, Financial intermediation, loanable funds, and the real sector, The Quarterly Journal of Economics, 112(3), 663-691.

Hördahl, P., O. Tristani, D. Vestin, 2006, A joint econometric model of macroeconomic and term-structure dynamics, Journal of Econometrics, 131, 405-444.

Iacoviello, M., 2005, House prices, borrowing constraints and monetary policy in the business cycle, American Economic Review, 95(3), 739-764.

Iacoviello, M., 2010, Financial business cycles, Working paper.

Imbs, J., 2006, The real effects of financial integration, Journal of International Economics, 68(2), 296-324.

Johansen, S., 1988, Statistical analysis of cointegration vectors, Journal of Economic Dynamics and Control, 12, 231-254.

Johansen, S., 1992, Cointegration in partial systems and the efficiency of single-equation analysis, Journal of Econometrics, 52(3), 389-402.

Johansen, S., 1995, Likelihood-based inference in cointegrated vector autoregressive models, Oxford University Press, Oxford.

Johansen, S., 2000, Modelling of cointegration in the vector autoregressive model, Economic Modelling, 17, 359-373.

Johansen, S., Juselius, K., 1990, Maximum likelihood estimation and inference on cointegration – with applications to the demand for money, Oxford Bulletin of Economics and Statistics, 52, 169-210.

Joslin, S., K.J. Singleton, H. Zhu, 2010, A New Perspective on Gaussian DTSMs, Review of Financial Studies, forthcoming.

Kalemli-Ozcan, S., B. Sorensen, O. Yosha, 2003, Risk sharing and industrial specialization: regional and international evidence, American Economic Review, 93, 903–918.

Kashyap, A., R. Rajan, J. Stein, 2008, Rethinking Capital Regulation, Kansas City Symposium on Financial Stability.

Kilian, L., 1998, Small-sample confidence intervals for impulse response functions, The Review of Economics and Statistics, 80(2), 218-230.

Koop, G., M. H. Pesaran, S. M. Potter, 1996, Impulse response analysis in nonlinear multivariate models, Journal of Econometrics, 74(1), 119–147.

Kose, M.A., C. Otrok, C. Whiteman, 2008, Understanding the evolution of world business cycles, Journal of International Economics, 75(1), 110-130.

Kose, M.A., C. Otrok, E.S. Prasad, 2008, Global business cycles: convergence or decoupling?, IMF Working Paper, WP/08/143.

Kose, M.A., E.S. Prasad, M. Terrones, 2003, How does globalization affect the synchronization of business cycles?, American Economic Review - Papers and Proceedings, 93, 57–62.

Lemke, W., T. Werner, 2009, The term structure of equity premia in an affine arbitrage-free model of bond and stock market dynamics, ECB Working Paper Series, No. 1045.

Litterman, R., J.A. Scheinkman, 1991, Common factors affecting bond returns, Journal of Fixed Income, 1, 51-61.

Mackinnon, J.G., A.A. Haug, L. Michelis, 1999, Numerical distribution functions of likelihood ratio tests for cointegration, Journal of Applied Econometrics, 14, 563-577.

Meh, C. A., K. Moran, 2010, The role of bank capital in the propagation of shocks, Journal of Economic Dynamics and Control, 34(3), 555-576.

Mitchell, J., R.J. Smith, M.R. Weale, S. Wright, E.L. Salazar, 2005, An indicator of monthly GDP an an early estimate of quarterly GDP growth, The Economic Journal, 115, F108-F129.

Moench, E., 2008, Forecasting the yield curve in a data-rich environment: A no-arbitrage factor-augmented VAR approach, Journal of Econometrics, 146, 26-43.

Nelson, C.R., A.F. Siegel, 1987, Parsimonoius modeling of yield curves, Journal of Business 60(4), 473-489.

Neri, S., M. Iacoviello, 2008, Housing market spillovers: evidence from an estimated DSGE model, Banca d'Italia, Working Paper No. 659.

Nyblom, J., 1989, Testing for the constancy of parameters over time, Journal of the American Statistical Association, 84, 223-230.

Pagan, A.R., M.H. Pesaran, 2008, Econometric analysis of structural systems with permanent and transitory shocks, Journal of Economic Dynamics and Control, 32, 3376-3395.

Pesaran, M.H., 2006, Estimation and interference in large heterogeneous panels with a multifactor error structure, Econometrica, 74(4), 967-1012.

Pesaran, M.H., T. Schuermann, S.M. Weiner, 2004, Modeling regional interdependencies using a global error-correcting macroeconomic model, Journal of Business and Economic Statistics, 22, 129-162.

Pesaran, M.H., Y. Shin, R.J. Smith, 2000, Structural analysis of vector error correction models with exogenous I(1) variables, Journal of Econometrics, 97, 293-343.

Pesaran, M.H., L.V. Smith, R.P. Smith, 2007, What if the UK or Sweden had joined the Euro in 1997? An empirical evaluation using a global VAR, International Journal of Finance and Economics, 12, 55-87.

Pesaran, M.H., R. Smith, 2006, Macroeconomic modelling with a global perspective, The Manchester School, 24-49.

Pesaran, M.H., Y. Shin, 1998, Generalized impulse response analysis in linear multivariate models, Economic Letters, 58, 17-29.

Pesaran, M.H., Y. Shin, 2002, Long-run structural modelling, Econometric Reviews 21(1), 49-87.

Piazzesi, M., 2003, Affine term structure models, Working Paper.

Piazzesi, M., M. Schneider, 2010, Trend and cycle in bond premia, Working Paper.

Ploberger, W., W. Kraemer, 1992, The CUSUM test with OLS residuals, Econometrica, 60(2), 271-285.

Quandt, R.E., 1960, Tests of hypotheses that a linear system obeys two separate regimes, Journal of the American Statistical Association, 55, 324-330.

Salazar, E.L., R.J. Smith, M.R. Weale, 1997, Interpolation using a dynamic regression model: specification and Monte Carlo properties, NIESR, Discussion Paper no. 126.

Sims, C., T. Zha, 2006, Does monetary policy generate recessions? Macroeconomic Dynamics, 10, 231–272.

Sims, C.A., 1980, Macroeconomics and reality, Econometrica, 48(1), 1-48.

Sims, C.A., T. Zha, 2006, Does monetary policy generate recessions? Macroeconomic Dynamics, 10, 231–272.

Smets, F., 2003, Maintaining price stability: how long is the medium term?, Journal of Monetary Economics, 50, 1293-1309.

Spencer, P., Z. Liu, 2010, An open-economy macro-finance model of international interdependence: The OECD, US and the UK, Journal of Banking and Finance, 34, 667-680.

Su, L., S. Jin, 2009, Sieve estimation of panel data models with cross section dependence, Working paper.

US Treasury Department, 2009, Principles for Reforming the U.S. and International Regulatory Capital Framework for Banking Firms, Policy statement.

Vansteenkiste, I., 2007, Regional housing market spillovers in the US: lessons from regional divergences in a common monetary policy setting, ECB Working Paper Series, No. 708.

Walsh, C. E., 2009, Using monetary policy to stabilize economic activity, Jackson Hole Symposium, 2010: 245-296.

Appendix A

Appendix to Chapter 1

A.1 First order conditions

Note: for $(t+s)$-terms expectation operator is omitted for notational convenience.

A.1.1 Households

$$w_t = \bar{m}\frac{C_t}{(1-N_t)} \tag{A.1}$$

$$\frac{1-T_t}{C_t\left(1+r_t^l\right)} = \beta\frac{1}{C_{t+1}\pi_{t+1}} - \chi\left(\frac{D_t^h}{1+r_t^l} - \frac{\bar{D}^h}{1+\bar{r}^l}\right)\frac{1}{1+r_t^l} \tag{A.2}$$

A.1.2 Non-financial firms

$$Y_N = w_t \tag{A.3}$$

$$Y_K = \lambda_t - \bar{\beta}_{t+1}\left(1-\tau\right)\lambda_{t+1} \tag{A.4}$$

$$\frac{\lambda_t}{1+r_t^b} = \bar{\beta}_{t+1}\frac{\alpha_{t+1}}{\pi_{t+1}} + \bar{\beta}_{t+2}\gamma\frac{\left(1-\alpha_{t+1}\right)^2}{\pi_{t+1}}\left(\frac{L_t^f}{\pi_{t+1}} + d_f\right) \tag{A.5}$$

$$\frac{L_{t-1}^f}{\pi_t} = \bar{\beta}_{t+1}\gamma\left(1-\alpha_t\right)\left(\frac{L_{t-1}^f}{\pi_t} + d_f\right)^2 \tag{A.6}$$

$$\theta\left(1-mc_t\right) = 1 - \psi\left(\pi_t - \pi^*\right)\pi_t - \bar{\beta}_{t+1}\psi\left(\pi_{t+1} - \pi^*\right)\pi_{t+1}\frac{Y_{t+1}}{Y_t} \tag{A.7}$$

$$mc_t = \exp\left(A_t\right)^{\eta-1}\left(r_t^b\frac{\left(1+r_t^b\right)}{\eta}\right)^{\eta}\left(\frac{w_t}{1-\eta}\right)^{1-\eta} \tag{A.8}$$

A.1.3 Deposit banks

$$\frac{\lambda_t^l}{1+r_t^l}=\bar{\beta}_{t+1}\frac{\lambda_{t+1}^l}{\pi_{t+1}} \tag{A.9}$$

$$\frac{\lambda_t^l}{1+i_t}=\bar{\beta}_{t+1}\frac{\delta_{t+1}\lambda_{t+1}^l}{\pi_{t+1}}+\bar{\beta}_{t+2}\zeta_l\left(1-\delta_{t+1}\right)\frac{\lambda_{t+2}^l}{\pi_{t+1}}-d_{F^l}kw^l-b_{F^l}h \tag{A.10}$$

$$d_{F^l}v_l=\left(\lambda_t^l\left(1+v_lr_t\right)-\frac{1}{\Pi_t^l}\right)-\bar{\beta}_{t+1}\left(1-\xi_l+\varpi_l\right)\left(\lambda_{t+1}^l-\frac{1}{\Pi_{t+1}^l}\right)\frac{1}{\pi_{t+1}} \tag{A.11}$$

A.1.4 Lending banks

$$\frac{\lambda_t^b}{1+i_t}=\bar{\beta}_{t+1}\frac{\lambda_{t+1}^b\delta_{t+1}}{\pi_{t+1}}+\bar{\beta}_{t+2}\lambda_{t+2}^b\omega\frac{\left(1-\delta_{t+1}\right)^2}{\pi_{t+1}}\left(\frac{D_t^{bd}}{\pi_{t+1}}+d_\delta\right) \tag{A.12}$$

$$\frac{\lambda_t^b}{1+r_t^b}=\bar{\beta}_{t+1}\frac{\alpha_{t+1}\lambda_{t+1}^b}{\pi_{t+1}}+\bar{\beta}_{t+2}\zeta_b\left(1-\alpha_{t+1}\right)\frac{\lambda_{t+2}^b}{\pi_{t+1}}-d_{F^b}kw^b-b_{F^b}h \tag{A.13}$$

$$\frac{\lambda_t^bD_{t-1}^{bd}}{\pi_t}=\bar{\beta}_{t+1}\lambda_{t+1}^b\omega\left(1-\delta_t\right)\left(\frac{D_{t-1}^{bd}}{\pi_t}+d_\delta\right)^2 \tag{A.14}$$

$$d_{F^b}v_b=\left(\lambda_t^b\left(1+v_br_t\right)-\frac{1}{\Pi_t^b}\right)-\bar{\beta}_{t+1}\left(1-\xi_b+\varpi_b\right)\left(\lambda_{t+1}^b-\frac{1}{\Pi_{t+1}^b}\right)\frac{1}{\pi_{t+1}} \tag{A.15}$$

A.2 Tables

Table A.1: GDP and consumption loss for a model with exogenous solvency rates

	basis scenario	$M_t^b + M_t^l$	M_t^f	$x_t^b + x_t^l$	$k(Y)$	$\varpi_b F_t^b + \varpi_l F_t^l$
	regulatory regime without leverage ratio ($b_{F^b} = b_{F^l} = 0$)					
$\frac{\sum_{t=1}^{T} \beta^t (gdp_t - gdp)}{gdp}$	-9.15%	-2.70%	5.64%	-8.45%	-9.13%	-8.52%
$\left(\frac{\sum_{t=1}^{T} (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.471%	0.880%	0.838%	0.464%	0.470%	0.458%
$\frac{\sum_{t=1}^{T} \beta^t (C_t - C)}{C}$	-2.72%	-0.51%	1.00%	-2.51%	-2.72%	-2.76%
$\left(\frac{\sum_{t=1}^{T} (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.240%	0.351%	0.251%	0.241%	0.240%	0.240%
$\left(\frac{\sum_{t=1}^{T} (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.231%	0.681%	0.859%	0.224%	0.236%	0.234%
	regulatory regime with leverage ratio ($b_{F^b} = b_{F^l} = 10$)					
$\frac{\sum_{t=1}^{T} \beta^t (gdp_t - gdp)}{gdp}$	-8.74%	-1.50%	5.69%	-7.67%	-8.70%	-8.15%
$\left(\frac{\sum_{t=1}^{T} (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.458%	0.905%	0.843%	0.449%	0.456%	0.446%
$\frac{\sum_{t=1}^{T} \beta^t (C_t - C)}{C}$	-2.58%	0.11%	1.12%	-2.27%	-2.58%	-2.63%
$\left(\frac{\sum_{t=1}^{T} (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.236%	0.353%	0.252%	0.236%	0.235%	0.236%
$\left(\frac{\sum_{t=1}^{T} (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.178%	0.657%	0.719%	0.175%	0.179%	0.179%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a positive 2,5% and 5% shocks to firm and lending banks default rates, respectively, in a model with exogenous solvency rates. Consequent columns present results of quantitative easing to banks, quantitative easing to firms, qualitative easing to banks, regime switch to output driven capital ratio and capital injection to banks, respectively, amounting to 5% of GDP each. T = 30.

Table A.2: GDP and consumption loss for a model with no interbank market and endogenous solvency rates

	basis scenario	M_t^l	M_t^f	x_t^l	$k(Y)$	$\varpi_l F_t^l$
	regulatory regime without leverage ratio ($b_{F^l} = 0$)					
$\frac{\sum_{t=1}^{T} \beta^t (gdp_t - gdp)}{gdp}$	-17.84%	-14.24%	-16.75%	-17.23%	-17.17%	-17.46%
$\left(\frac{\sum_{t=1}^{T} (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.581%	1.280%	1.294%	0.566%	0.561%	0.569%
$\frac{\sum_{t=1}^{T} \beta^t (C_t - C)}{C}$	-11.18%	-9.87%	-10.46%	-10.75%	-11.04%	-11.26%
$\left(\frac{\sum_{t=1}^{T} (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.185%	0.167%	0.182%	0.178%	0.182%	0.186%
$\left(\frac{\sum_{t=1}^{T} (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.011%	0.102%	0.123%	0.014%	0.017%	0.010%
	regulatory regime with leverage ratio ($b_{F^l} = 10$)					
$\frac{\sum_{t=1}^{T} \beta^t (gdp_t - gdp)}{gdp}$	-17.84%	-14.29%	-16.82%	-17.17%	-17.13%	-17.45%
$\left(\frac{\sum_{t=1}^{T} (gdp_t - gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.581%	1.279%	1.292%	0.564%	0.560%	0.568%
$\frac{\sum_{t=1}^{T} \beta^t (C_t - C)}{C}$	-11.18%	-9.92%	-10.52%	-10.69%	-11.03%	-11.27%
$\left(\frac{\sum_{t=1}^{T} (C_t - C)^2}{T-1}\right)^{\frac{1}{2}}$	0.185%	0.167%	0.182%	0.177%	0.182%	0.186%
$\left(\frac{\sum_{t=1}^{T} (\pi_t - \pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.011%	0.099%	0.118%	0.015%	0.016%	0.010%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a negative two standard deviations technology shock; consequent columns present results of quantitative easing to banks, quantitative easing to firms, qualitative easing to banks, regime switch to output driven capital ratio and capital injection to banks, respectively, amounting to 5% of GDP each. T = 30. Model with endogenous solvency rate for firms and homogenous banking sector which offers deposits to households, lends to firms and is not subject to default.

Table A.3: GDP and consumption loss for a model with exogenous solvency rates

	basis scenario	$M_t^b+M_t^l$	M_t^f	$x_t^b+x_t^l$	$\varpi_b F_t^b+\varpi_l F_t^l$
	regulatory regime without leverage ratio ($b_{F^b}=b_{F^l}=0$)				
$\frac{\sum_{t=1}^{T}\beta^t(gdp_t-gdp)}{gdp}$	-9.15%	-1.48%	7.52%	-8.41%	-8.52%
$\left(\frac{\sum_{t=1}^{T}(gdp_t-gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.471%	0.854%	0.963%	0.462%	0.458%
$\frac{\sum_{t=1}^{T}\beta^t(C_t-C)}{C}$	-2.72%	-0.20%	1.74%	-2.50%	-2.76%
$\left(\frac{\sum_{t=1}^{T}(C_t-C)^2}{T-1}\right)^{\frac{1}{2}}$	0.240%	0.335%	0.289%	0.240%	0.241%
$\left(\frac{\sum_{t=1}^{T}(\pi_t-\pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.231%	0.530%	0.992%	0.222%	0.234%
	regulatory regime with leverage ratio ($b_{F^b}=b_{F^l}=10$)				
$\frac{\sum_{t=1}^{T}\beta^t(gdp_t-gdp)}{gdp}$	-8.74%	-0.26%	7.54%	-7.62%	-8.16%
$\left(\frac{\sum_{t=1}^{T}(gdp_t-gdp)^2}{T-1}\right)^{\frac{1}{2}}$	0.458%	0.880%	0.995%	0.447%	0.446%
$\frac{\sum_{t=1}^{T}\beta^t(C_t-C)}{C}$	-2.58%	0.04%	1.65%	-2.26%	-2.64%
$\left(\frac{\sum_{t=1}^{T}(C_t-C)^2}{T-1}\right)^{\frac{1}{2}}$	0.236%	0.331%	0.288%	0.235%	0.236%
$\left(\frac{\sum_{t=1}^{T}(\pi_t-\pi)^2}{T-1}\right)^{\frac{1}{2}}$	0.178%	0.759%	0.558%	0.172%	0.179%

Note: Table shows present value of GDP and consumption loss as well as variation in GDP, consumption and inflation rate after positive shocks to default rates and subsequent central bank actions. First column shows results for a basis scenario consisting of a positive 2,5% and 5% shocks to firm and lending banks default rates, respectively; consequent columns present results of quantitative easing to banks, quantitative easing to firms, qualitative easing to banks and capital injection to banks, respectively, amounting to 5% of GDP each. T = 30. Model with exogenous solvency rates.

Table A.4: Calibrated parameter values

households		firms		banks				monetary policy	
$\bar{r}^l$	0.0035	θ	4.24	k	0.08	ω	367	Q_p	1.2
χ	0.01	ψ	50	h	0.04	d_δ	0.02	Q_y	0.05
$\bar{D}^l$	0.39	ρ_a	0.95			$\bar{\rho}$	0.01	$\bar{r}$	0.0015
β	0.9965	η	0.333	$\bar{B}^l$	0.19	$\bar{B}^b$	0.19	μ_r	0.7
$\bar{m}$	3.72	τ	0.03	d_{F^l}	53.4	d_{F^b}	6.71	π^*	1
		γ	103.5	ζ_l	0.8	ζ_b	0.8	Q_k	0.5
		d_f	0.001	ξ_l	0.07	ξ_b	0.06		
				v_l	0.5	v_b	0.5		
				w^l	0.05	w^b	0.8		
				$\rho_{M^{(\cdot)}}$	0.85	$\rho_{x^{(\cdot)}}$	0.85		
				b_{F^l}	10	b_{F^b}	10		

Table A.5: Steady state values

Variable	Definition	Value			
		endogenous default rates		exogenous default rates	
	steady state values	$b_{F(\cdot)} = 0$	$b_{F(\cdot)} = 10$	$b_{F(\cdot)} = 0$	$b_{F(\cdot)} = 10$
π	inflation	1.0009	1.0034	1.0003	1.0031
r	central bank interest rate	0.0050	0.0154	0.0028	0.0138
r^l	deposit interest rate	0.0044	0.0070	0.0038	0.0066
i	interbank interest rate	0.0091	0.0122	0.0081	0.0111
r^b	firms' borrowing interest rate	0.0161	0.0201	0.0154	0.0195
α	solvency rate: firms	0.9490	0.9490	0.9500	0.9500
δ	solvency rate: lending banks	0.9774	0.9766	0.9800	0.9800
mc	marginal cost of production	0.7848	0.8454	0.7720	0.8362
w	wage	2.0895	2.0880	2.0907	2.0893
	steady state ratios				
C/Y	consumption to output	0.7138	0.7138	0.7136	0.7135
K/Y	capital stock to output	9.8231	9.8098	9.8347	9.8220
Π^f/Y	firms' profits to output	0.0418	0.0418	0.0415	0.0415
Π^b/Y	lending banks' profits to output	0.0051	0.0051	0.0052	0.0051
Π^l/Y	deposit banks' profits to output	0.0013	0.0012	0.0013	0.0013
F^b/Y	lending banks' own funds to output	0.0422	0.0403	0.0427	0.0403
F^l/Y	deposit banks' own funds to output	0.0088	0.0080	0.0095	0.0087
D^l/gdp	deposits to GDP	0.6134	0.6157	0.6125	0.6148
D^{bs}/gdp	interbank lending to GDP	0.1192	0.1121	0.1383	0.1358
L^b/gdp	firms' borrowing to GDP	0.2960	0.2969	0.2961	0.2970

Table A.6: Second moments (model with endogenous default rates and no leverage ratio)

Variable	σ
π	0.00106
K	0.21568
N	0.00264
Y	0.02222
C	0.01102
w	0.05478
gdp	0.02221

Table A.7: Prior and posterior distributions of parameters and shocks

	prior distribution			posterior distribution			
parameter	distr.	mean	st.dev.	mean	2.50%	median	97.50%
ε_t^A	Inv. Gamma	0.01	Inf	0.0102	0.0089	0.0101	0.0119
ε_t^r	Inv. Gamma	0.01	Inf	0.0035	0.0031	0.0035	0.0040
ε_t^T	Inv. Gamma	0.01	Inf	0.0020	0.0016	0.0020	0.0025
$\varepsilon_t^{M^b}$	Inv. Gamma	0.01	Inf	0.0035	0.0022	0.0034	0.0050
$\varepsilon_t^{M^l}$	Inv. Gamma	0.01	Inf	0.0034	0.0021	0.0034	0.0050
$\varepsilon_t^{M^f}$	Inv. Gamma	0.01	Inf	0.0037	0.0022	0.0036	0.0056
$\varepsilon_t^{x^b}$	Inv. Gamma	0.01	Inf	0.0092	0.0018	0.0074	0.0248
$\varepsilon_t^{x^l}$	Inv. Gamma	0.01	Inf	0.0080	0.0020	0.0066	0.0188
θ	Gamma	4.24	0.1	4.045	3.879	4.047	4.206
ψ	Gamma	50	1.5	51.815	48.921	51.746	54.932
γ	Gamma	103.5	2.5	101.475	94.001	101.496	108.702
$\bar{m}$	Gamma	3.72	0.1	3.670	3.485	3.667	3.851
ω	Gamma	367	25	359.384	329.705	357.865	390.533
d_{F^b}	Gamma	6.71	0.3	6.803	6.188	6.810	7.419
d_{F^l}	Gamma	53.4	1.5	52.987	50.152	52.978	55.946
η	Beta	0.3333	0.02	0.334	0.327	0.334	0.341
$\bar{r}$	Gamma	0.0015	0.0005	0.0008	0.0004	0.0007	0.0013
$\bar{r}^l$	Gamma	0.0035	0.001	0.0036	0.0017	0.0035	0.0057
μ_r	Beta	0.7	0.15	0.403	0.233	0.407	0.560
Q_p	Gamma	1.2	0.1	1.025	1.006	1.023	1.051
Q_y	Beta	0.05	0.02	0.043	0.016	0.041	0.080

Note: Results based on 2 chains, each with 10,000 draws Metropolis algorithm.

A.3 Figures

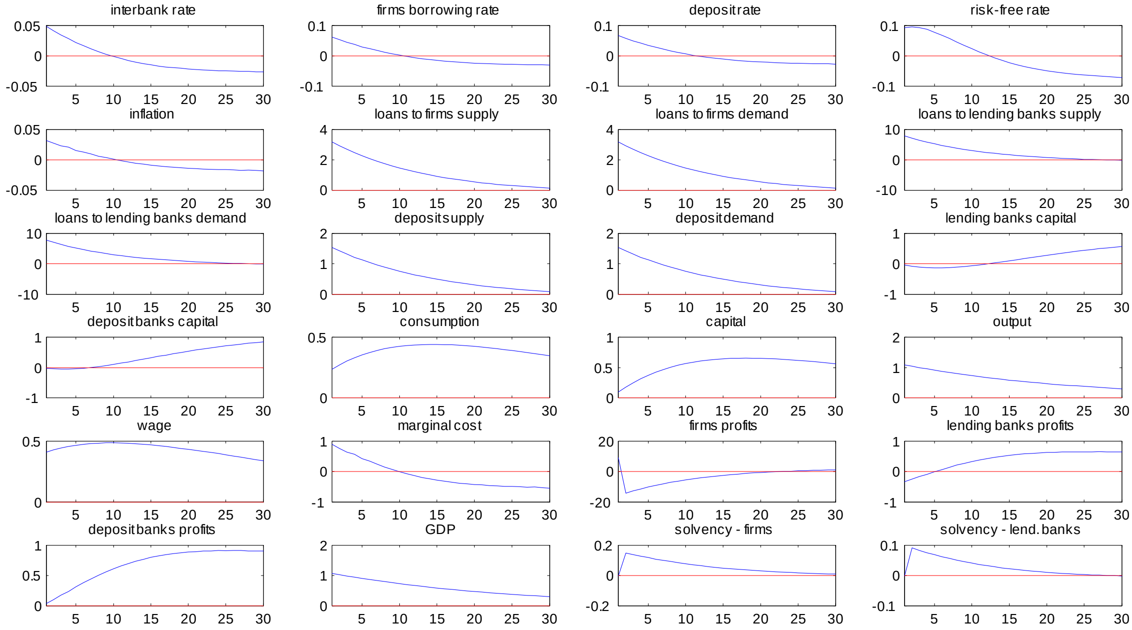

Figure A.1: Responses to positive technology shock.

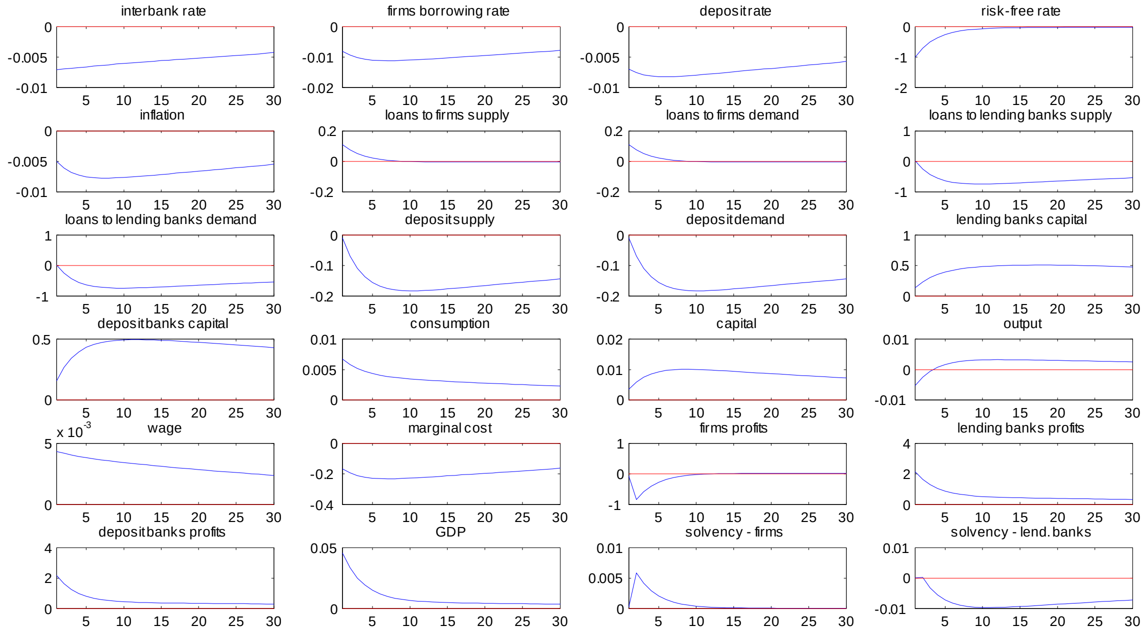

Figure A.2: Responses to expansionary monetary policy shock.

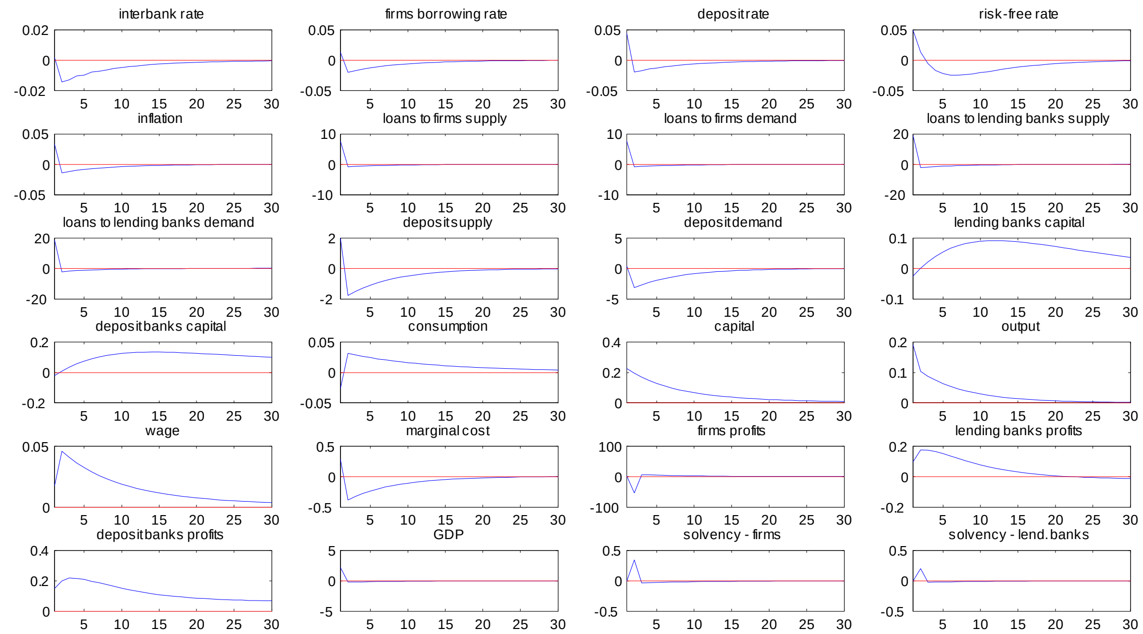

Figure A.3: Responses to positive quantitative monetary easing shock to deposit banks.

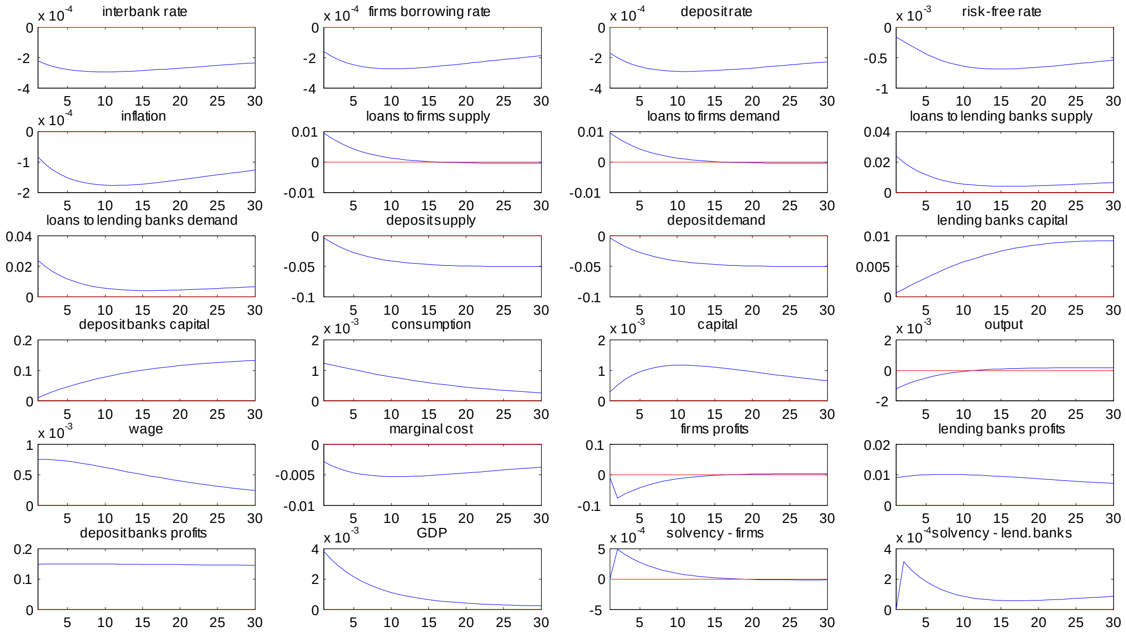

Figure A.4: Responses to positive qualitative monetary easing shock to deposit banks.

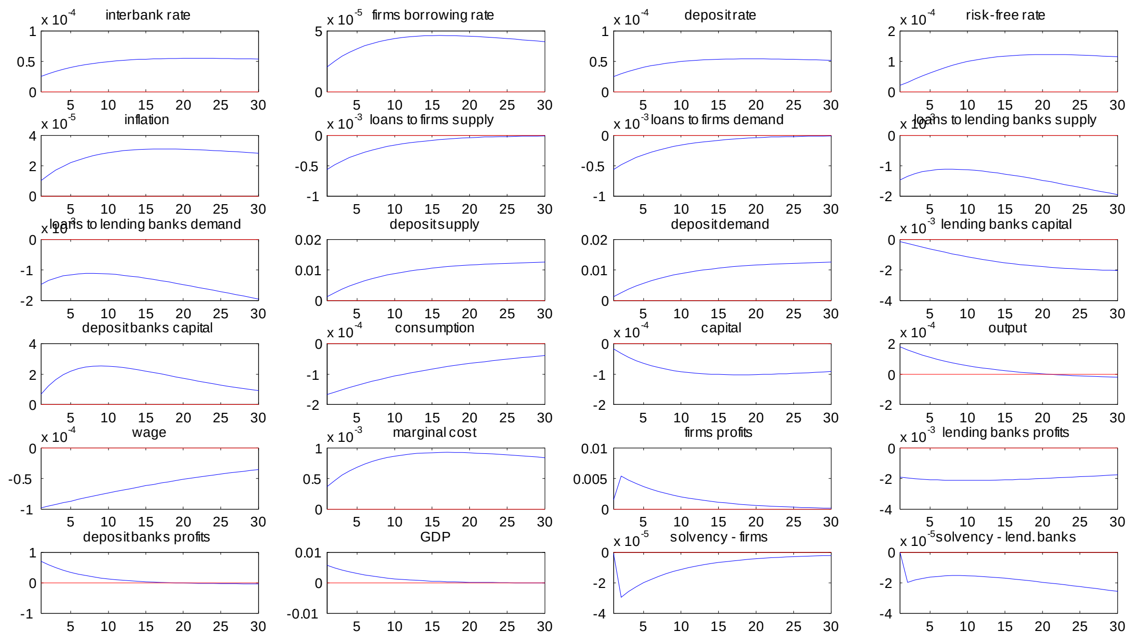

Figure A.5: Responses to positive capital shock to deposit banks.

Appendix B

Appendix to Chapter 2

B.1 Bond prices

A_n and B_n are derived as follows:

Plugging the expressions for $p_t^{(n)}$ and m_t from equations (2.20) and (2.23) into equation (2.22) we get:

$$\begin{aligned}
p_t^{(n)} &= E_t\left[M_{t+1}p_{t+1}^{(n-1)}\right] \qquad (B.1)\\
&= E_t\left[\exp\left(-r_t - \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t - \lambda_t' H\zeta_{t+1}\right)\exp\left(A_{n-1} + B_{n-1}' z_{t+1}\right)\right]\\
&= \exp\left(-r_t - \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t + A_{n-1}\right) E_t\left[\exp\left(-\lambda_t' H\zeta_{t+1} + B_{n-1}'\left(\mu + \{\Phi_i\} z_t + H\zeta_{t+1}\right)\right)\right]\\
&= \exp\left(-r_t - \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t + A_{n-1} + B_{n-1}'\left(\mu + \{\Phi_i\} z_t\right)\right) E_t\left[\exp\left(\left(-\lambda_t' + B_{n-1}'\right) H\zeta_{t+1}\right)\right]
\end{aligned}$$

Innovations ζ_t of the process for state variables are assumed to be Gaussian with mean zero and covariance matrix $\Sigma_{\zeta\zeta}$, therefore:

$$\begin{aligned}
\ln E_t\left[\exp\left(\left(-\lambda_t' + B_{n-1}'\right) H\zeta_{t+1}\right)\right] &= E_t\left[\ln\left(\exp\left(\left(-\lambda_t' + B_{n-1}'\right) H\zeta_{t+1}\right)\right)\right] + \qquad (B.2)\\
&\quad \frac{1}{2}Var_t\left[\ln\left(\exp\left(\left(-\lambda_t' + B_{n-1}'\right) H\zeta_{t+1}\right)\right)\right]\\
&= \frac{1}{2}\left[\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t - 2B_{n-1}' H\Sigma_{\zeta\zeta}H'\lambda_t + B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1}\right]\\
&= \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t - B_{n-1}' H\Sigma_{\zeta\zeta}H'\lambda_t + \frac{1}{2}B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1}
\end{aligned}$$

Now, using

$$E_t\left[\exp\left(\left(-\lambda_t' + B_{n-1}'\right) H\zeta_{t+1}\right)\right] = \exp\left(\frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t - B_{n-1}' H\Sigma_{\zeta\zeta}H'\lambda_t + \frac{1}{2}B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1}\right) \qquad (B.3)$$

together with equations (2.19) and (2.21) we obtain:

$$
\begin{aligned}
p_t^{(n)} &= \exp\left(\begin{array}{c} -r_t - \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t + A_{n-1} + B_{n-1}'\left(\mu + \{\Phi_i\} z_t\right) + \\ \frac{1}{2}\lambda_t' H\Sigma_{\zeta\zeta}H'\lambda_t - B_{n-1}' H\Sigma_{\zeta\zeta}H'\lambda_t + \\ \frac{1}{2}B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1} \end{array}\right) \qquad \text{(B.4)} \\
&= \exp\left(\begin{array}{c} A_{n-1} + B_{n-1}'\left(\mu - H\Sigma_{\zeta\zeta}H'\lambda_0\right) + \frac{1}{2}B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1} - \delta_0 + \\ \left[B_{n-1}'\left(\{\Phi_i\} - H\Sigma_{\zeta\zeta}H'\lambda_1\right) - \delta_1'\right] z_t \end{array}\right)
\end{aligned}
$$

so that by means of matching coefficients the equation for bond prices can be written as:

$$
p_t^{(n)} = \exp\left(A_n + B_n' z_t\right) \qquad \text{(B.5)}
$$

where

$$
\begin{aligned}
A_n &= A_{n-1} + B_{n-1}'\left(\mu - H\Sigma_{\zeta\zeta}H'\lambda_0\right) + \frac{1}{2}B_{n-1}' H\Sigma_{\zeta\zeta}H' B_{n-1} - \delta_0 \qquad \text{(B.6)} \\
B_n &= B_{n-1}'\left(\{\Phi_i\} - H\Sigma_{\zeta\zeta}H'\lambda_1\right) - \delta_1'
\end{aligned}
$$

B.2 Tables

Table B.1: Autoregressive distributed lag models

	EC	LRC	ARDL(p,q)
PPP	-0.0816 $\underset{(0.0224)}{}$	$e_t = \underset{(0.7666)}{2.5128} + \underset{(3.569)}{11.051} cpi_t - \underset{(1.810)}{4.754} cpi_t^* + \varepsilon_t$	ARDL(1,0,0)
GAP	-0.0109 $\underset{(0.0076)}{}$	$gdp_t = \underset{(0.0202)}{-0.0476} + \underset{(0.7687)}{1.9272} gdp_t^* + \varepsilon_t$	ARDL(4,1)
UIP	-0.0724 $\underset{(0.0294)}{}$	$r_t = \underset{(0.0001)}{-0.0001} + \underset{(0.1627)}{0.7914} r_t^* + \varepsilon_t$	ARDL(1,1)
LIR	-0.0252 $\underset{(0.0099)}{}$	$r_t = \underset{(0.00002)}{0.00002} + \underset{(0.1991)}{0.1939} \pi_t + \varepsilon_t$	ARDL(1,0)

Note: EC denotes error-correcting term, LRC stands for long-run coefficients equation; last column reports lag order that is chosen according to SBC information criterion; standard errors in brackets take into account super-consistency (T-consistency) of long-run coefficients.

Table B.2: Tests of structural change

Test	$y_t^{(120)} - \bar{r}$	e_t	gdp_t	π_t	r_t	$cpi_t - cpi_t^*$
PK sup	0	0	1	1	0	1
PK msq	0	0	1	0	0	0
Nyblom	0	1	1	1	1	1
robust Nyblom	0	1	1	1	1	1
QLR	0	1	1	1	0	1
robust QLR	0	0	0	1	1	1
MW	0	1	1	1	0	1
robust MW	0	0	0	1	1	1
APW	0	1	1	1	0	1
robust APW	0	0	0	1	1	1

Note: Table display the rejections (1) per variable and test at 5% level.

Appendix C

Appendix to Chapter 3

C.1 Tables

Table C.1: Lag order in country-specific models

	x_{it}	x_{it}^*	d_t		x_{it}	x_{it}^*	d_t
Argentina	1	1	1	Japan	1	1	1
Australia	1	1	3	Korea	1	1	1
Austria	1	1	1	Latvia	1	1	1
Belgium	1	2	1	Malaysia	1	1	2
Brazil	1	1	3	Netherlands	1	1	1
Bulgaria	1	1	1	Norway	1	1	1
Canada	1	1	1	Poland	1	1	2
China (Mainland)	1	1	4	Portugal	1	1	1
Czech Republic	1	1	1	Russia	1	1	1
Denmark	1	1	2	Singapore	1	1	1
Estonia	2	1	1	Slovak Republic	1	1	1
Finland	1	1	1	Slovenia	1	1	1
France	1	1	1	South Africa	1	1	3
Germany	1	1	1	Spain	1	1	1
Greece	2	1	2	Sweden	1	1	1
Hungary	1	1	1	Switzerland	1	1	1
India	1	1	1	Thailand	1	1	1
Indonesia	1	1	1	Turkey	1	1	1
Ireland	1	1	1	United Kingdom	1	1	1
Italy	1	1	1	United States	1	1	1

Note: Bold numbers denote significance at 5%.

Table C.2: Unit root test results for global common variable (oil price index)

	d_t	Δd_t
ADF	-1,77	-8,62
ADF-GLS	-0,03	-2,74

Note: Statistics for level variables are based on regressions including linear trend; statistics for first differences include only intercept term. The 95% critical values are -3.4496 and -1.9436, respectively.

Table C.3: ADF-GLS unit root test results for domestic variables

	eq	Δeq	cc	Δcc	re	Δre	ir	Δir	gdp	Δgdp
Argentina	-1.32	-8.99	-0.88	-3.46	-1.48	-0.68	-1.72	-3.01	0.12	-2.35
Australia	-0.71	-3.32	-0.05	-3.16	-0.01	-1.12	-0.90	-3.82	-2.34	-0.78
Austria	-0.09	-2.46	-1.28	-5.59	-0.13	-1.59	-0.72	-3.50	-0.19	-3.26
Belgium	-1.19	-7.69	-1.04	-1.17	-0.64	-2.16	-0.72	-3.50	-0.10	-2.32
Brazil	-1.61	-3.54	-0.27	-2.85	-0.57	-6.25	-1.90	-2.94	-1.52	-5.27
Bulgaria	-0.39	-2.09	-1.18	-4.33	-0.82	-1.72	-0.97	-12.67	-2.34	-2.89
Canada	-1.08	-1.99	-2.03	-10.52	-0.47	-2.13	-0.57	-2.32	0.44	-2.18
China (Mainland)	-1.91	-3.96	-1.56	-3.48	-1.00	-3.16	-2.00	-3.50	-1.04	-5.44
Czech Republic	-1.30	-1.45	-0.22	-3.04	-1.68	-14.48	-0.83	-3.32	-0.28	-1.87
Denmark	-1.10	-2.06	-0.89	-1.39	-1.03	-3.42	-1.10	-2.38	0.12	-1.47
Estonia	-0.35	-6.08	-0.39	-1.13	-0.06	-1.68	-0.44	0.06	-0.29	-1.09
Finland	-1.41	-8.23	-1.43	-3.40	0.00	-2.51	-0.72	-3.50	0.48	-1.43
France	-1.10	-2.35	-0.42	-1.48	-0.62	-3.06	-0.72	-3.50	0.17	-2.19
Germany	-1.24	-2.13	-1.08	-3.33	-0.59	-1.37	-0.72	-3.50	-0.24	-2.54
Greece	-0.84	-1.44	-1.07	-2.38	-0.97	-0.36	-0.72	-3.50	-0.34	-1.22
Hungary	-0.44	-2.15	-2.33	-3.28	-1.10	-3.13	-1.68	-16.81	-0.07	-2.24
India	-1.28	-3.63	-1.53	-1.70	-1.56	-4.13	-1.13	-2.87	-1.33	-2.55
Indonesia	-1.67	-2.77	-1.19	0.12	-2.02	-2.17	-1.84	-6.97	-1.56	-2.90
Ireland	-1.01	-2.16	-1.33	-2.72	-1.39	-1.00	-0.72	-3.50	-0.83	-1.64
Italy	-0.58	-2.51	-0.91	-1.32	0.07	-1.47	-0.72	-3.50	0.01	-1.19
Japan	-0.66	-4.48	-2.45	-2.27	-0.77	-4.06	-1.31	-1.23	-0.01	-4.58
Korea	-2.35	-3.24	-1.34	-2.34	-1.28	-2.65	-1.57	-7.36	-0.05	-2.98
Latvia	-0.10	-6.18	0.01	-1.55	-0.70	-1.88	-1.20	-2.64	0.99	-1.30
Malaysia	-1.89	-1.66	-0.94	-1.72	-1.89	-1.91	-1.74	-2.71	0.32	-2.59
Netherlands	-0.97	-3.22	-1.52	-1.49	-1.43	-3.56	-0.72	-3.50	-1.05	-1.76
Norway	-0.80	-2.79	-0.88	-2.68	-0.53	-2.21	-0.98	-1.65	-0.57	-2.02
Poland	-1.23	-1.34	-0.03	-2.10	-0.84	-2.82	-1.25	-2.45	-0.51	-2.54
Portugal	-1.16	-3.29	-0.75	-1.85	-2.22	-0.30	-0.72	-3.50	-1.19	-1.48
Russia	-0.73	-0.99	-1.07	-2.77	-3.35	-10.72	-0.70	-2.87	0.84	-1.81
Singapore	-1.40	-4.56	-0.33	-2.86	-1.25	-4.43	-1.32	-3.02	-0.28	-2.91
Slovak Republic	-0.47	-2.94	-0.14	-3.65	-1.07	-2.35	-0.91	-2.38	-0.80	-1.69
Slovenia	-0.04	-1.96	-0.16	-1.99	-1.53	-0.82	-1.30	-5.86	-1.02	-0.71
South Africa	-1.57	-3.68	-0.88	-3.51	-1.83	-1.16	-0.80	-3.59	-0.46	-2.68
Spain	-1.11	-2.54	-0.29	-1.65	-0.18	-0.74	-0.72	-3.50	-0.29	-2.20
Sweden	-1.21	-2.95	-1.08	-1.97	-0.55	-2.67	-0.86	-2.27	0.19	-1.35
Switzerland	-0.89	-2.45	-0.50	-2.70	-1.18	-1.50	-1.40	-2.18	-0.78	-1.69
Thailand	-1.56	-2.21	-0.68	-4.23	-0.68	-2.22	-1.04	-5.46	-0.95	-1.40
Turkey	-1.44	-0.64	-0.25	-1.25	-1.42	-0.75	-2.27	-2.49	-1.13	-2.68
United Kingdom	-1.17	-2.25	-0.66	-4.07	-0.86	-1.46	-0.67	-1.41	-0.55	0.13
United States	-1.25	-2.35	-1.65	-3.01	-0.41	-3.28	-1.20	-3.14	-0.83	-6.53

Note: Statistics for level variables are based on regressions including linear trend; statistics for first differences include only intercept term. The 95% critical values are -3.4496 and -1.9436, respectively.

Table C.4: ADF-GLS unit root test results for country-specific foreign variables

	eq^*	Δeq^*	cc^*	Δcc^*	re^*	Δre^*	ir^*	Δir^*	gdp^*	Δgdp^*
Argentina	-1.14	-3.36	-0.01	-3.20	-0.63	-2.88	-1.89	-3.33	0.26	-1.19
Australia	-0.99	-3.00	-0.76	-5.57	0.05	-3.45	-0.84	-2.21	0.84	-0.16
Austria	-1.01	-2.42	-1.04	-5.00	0.03	-1.52	-1.00	-2.83	-0.76	-1.66
Belgium	-0.95	-2.70	-0.58	-2.87	-0.60	-2.69	-0.86	-2.30	0.71	0.02
Brazil	-0.96	-3.23	-2.25	-5.45	-0.54	-2.75	-1.51	-2.87	-0.31	-1.19
Bulgaria	-0.81	-1.93	0.12	-2.85	-0.40	-0.24	-1.53	-2.29	-0.82	-0.07
Canada	-1.07	-2.52	-1.16	-3.07	-0.41	-4.42	-0.78	-3.00	-0.02	-1.50
China (Mainland)	-0.93	-3.21	-0.63	-5.13	0.33	-3.32	-0.96	-3.33	-1.05	-0.80
Czech Republic	-0.90	-2.66	-0.44	-4.26	0.03	-1.50	-0.98	-2.42	0.48	-3.05
Denmark	-1.07	-2.95	-0.74	-5.68	0.36	-1.68	-0.78	-2.20	0.89	0.15
Estonia	-1.00	-3.20	-1.08	-6.20	-0.52	-1.75	-1.19	-2.20	-1.36	-0.86
Finland	-0.99	-3.11	-0.85	-5.57	0.30	-2.10	-1.13	-1.63	-1.27	-0.12
France	-0.93	-2.94	-0.71	-3.28	-0.26	-1.64	-0.96	-2.28	0.87	0.43
Germany	-0.77	-2.98	-0.07	-2.14	-0.49	-2.62	-1.09	-2.22	0.74	0.44
Greece	-0.88	-3.02	-0.46	-4.45	-0.47	-2.04	-1.25	-2.05	-1.00	0.30
Hungary	-0.90	-3.00	-0.61	-5.12	0.14	-1.69	-1.10	-2.21	-0.99	-1.10
India	-1.03	-3.11	-0.33	-5.03	0.29	-3.56	-1.10	-2.76	0.66	-0.11
Indonesia	-1.06	-3.34	-0.01	-3.15	-0.30	-3.21	-0.95	-4.44	0.71	-1.62
Ireland	-0.98	-2.98	-0.66	-1.97	-0.56	-2.04	-0.79	-2.08	0.82	0.31
Italy	-0.94	-2.92	-0.38	-2.30	-0.62	-1.44	-1.22	-2.20	0.81	0.00
Japan	-1.12	-2.52	-0.67	-5.36	0.30	-4.14	-0.82	-6.43	0.45	-0.76
Korea	-1.01	-2.95	-0.65	-5.44	0.18	-3.59	-0.95	-2.74	0.21	-0.93
Latvia	-0.93	-3.24	-0.37	-4.91	0.27	-1.72	-1.09	-1.33	-1.68	-1.51
Malaysia	-1.00	-3.20	-0.38	-5.75	0.20	-3.31	-0.76	-2.26	0.80	-0.12
Netherlands	-0.97	-2.83	-0.71	-2.22	-0.35	-1.77	-0.92	-2.49	-0.56	0.32
Norway	-1.04	-2.88	-0.88	-5.50	0.32	-1.97	-0.84	-2.13	1.15	0.40
Poland	-0.94	-3.10	-0.73	-4.35	0.28	-1.63	-1.19	-2.16	-1.09	-1.24
Portugal	-1.05	-3.09	-0.47	-6.35	-0.14	-0.28	-0.89	-3.38	-0.15	0.25
Russia	-0.92	-2.91	-0.04	-3.15	0.19	-2.16	-1.37	-2.18	0.53	-0.58
Singapore	-0.95	-2.78	-0.74	-5.58	0.23	-3.54	-0.83	-2.20	0.98	-0.02
Slovak Republic	-0.84	-2.70	-0.34	-4.70	-0.34	-1.53	-1.02	-2.78	-1.26	-2.78
Slovenia	-0.74	-2.99	-0.59	-4.34	-0.28	-1.74	-1.12	-2.74	-0.56	-0.63
South Africa	-0.97	-2.74	-0.54	-5.15	0.44	-2.99	-0.88	-2.50	0.81	-0.14
Spain	-0.93	-2.85	-0.75	-2.85	0.29	-2.23	-1.13	-2.52	0.79	0.36
Sweden	-0.94	-2.72	-1.45	-6.16	0.24	-2.28	-0.94	-2.02	1.08	0.15
Switzerland	-1.00	-2.85	-0.79	-4.54	-0.31	-3.68	-0.77	-2.70	-0.66	-0.15
Thailand	-0.94	-3.14	-0.80	-3.26	0.01	-3.41	-0.95	-2.53	0.77	-1.07
Turkey	-0.88	-3.08	-0.52	-4.83	-0.44	-1.75	-1.12	-2.64	-1.31	-0.05
United Kingdom	-0.93	-2.53	-0.71	-2.71	-0.38	-2.46	-0.90	-2.60	0.61	-1.32
United States	-0.89	-2.80	-0.57	-6.52	-0.11	-3.05	-0.86	-2.28	0.72	-0.19

Note: Statistics for level variables are based on regressions including linear trend; statistics for first differences include only intercept term. The 95% critical values are -3.4496 and -1.9436, respectively.

Table C.5: Results of F-tests for weak exogeneity

	crit. val.	eq^*	cc^*	re^*	ir^*	gdp^*	d_t
Argentina	2.70	0.72	0.25	2.39	0.18	0.83	2.25
Australia	3.09	1.59	0.20	0.63	1.00	1.44	1.49
Austria	3.94	0.96	2.88	0.04	1.50	**9.30**	0.14
Belgium	3.09	1.39	2.21	1.39	0.91	**4.94**	**3.49**
Brazil	3.94	0.06	**4.18**	0.18	**8.45**	0.09	0.33
Bulgaria	3.09	0.08	0.65	0.01	0.10	**3.42**	0.11
Canada	3.09	0.15	0.10	**3.70**	0.67	**3.44**	0.56
China (Mainland)	2.31	0.43	0.58	0.76	**3.12**	1.24	1.77
Czech Republic	2.70	0.63	2.62	1.27	1.90	1.26	0.70
Denmark	3.09	0.56	**8.01**	0.26	0.64	1.98	0.53
Estonia	2.46	1.51	1.96	2.12	0.66	1.16	1.25
Finland	2.70	0.36	0.28	0.17	0.24	1.81	0.45
France	3.09	0.14	2.35	0.30	1.91	0.25	0.49
Germany	3.94	0.05	0.37	1.11	1.39	0.07	0.07
Greece	2.70	0.08	2.21	0.51	0.70	1.17	1.34
Hungary	2.70	0.32	0.30	0.59	0.86	0.60	1.40
India	3.09	0.61	1.57	0.95	0.41	0.02	0.70
Indonesia	3.09	2.05	**3.11**	**5.06**	0.15	**3.80**	0.09
Ireland	3.94	0.13	0.00	**5.88**	2.41	0.07	0.17
Italy	2.70	0.09	1.05	0.32	0.31	0.30	0.30
Japan	3.09	0.26	2.54	0.08	1.34	**3.34**	2.52
Korea	3.94	0.01	2.16	0.04	1.08	0.06	1.14
Latvia	3.94	0.54	0.12	3.34	0.12	2.18	0.15
Malaysia	2.70	0.48	0.08	0.56	1.91	0.13	0.98
Netherlands	2.70	0.52	0.65	0.51	0.59	1.01	1.57
Norway	3.09	0.13	1.86	1.49	2.00	**3.56**	0.11
Poland	2.70	2.21	1.27	0.04	**5.27**	1.36	0.65
Portugal	3.09	0.12	1.51	1.64	0.37	1.16	1.94
Russia	3.94	1.18	0.72	0.01	3.35	**3.95**	0.01
Singapore	3.09	0.31	1.08	1.13	**3.91**	0.87	0.42
Slovak Republic	3.09	0.73	2.69	1.47	0.53	2.08	0.49
Slovenia	2.46	1.07	1.22	0.16	1.15	1.70	0.36
South Africa	2.70	0.31	1.91	1.32	0.72	0.91	0.06
Spain	3.94	1.07	2.19	0.01	1.82	0.83	0.82
Sweden	3.09	1.28	0.68	0.41	0.26	0.47	0.17
Switzerland	3.09	0.30	0.58	2.05	0.06	0.80	0.93
Thailand	3.09	0.40	1.04	0.77	1.14	0.53	0.32
Turkey	2.70	0.08	1.86	0.19	0.25	0.23	1.30
United Kingdom	3.94	0.25	2.69	1.38	0.94	0.45	1.05
United States	3.09	2.51	1.01	1.32	0.19	-	-

Note: Bold numbers denote significance at 5%.

Table C.6: Contemporaneous effects of foreign variables on their domestic counterparts

	eq	*cc*	*re*	*ir*	*gdp*
Argentina	0.82 (3.24)	-0.21 (-0.51)	0.04 (0.32)	6.04 (1.63)	0.48 (1.5)
Australia	0.57 (8.45)	0.29 (1.38)	0.37 (2.6)	1.17 (3.64)	1.02 (2.01)
Austria	0.19 (1.33)	1.12 (4.61)	0.86 (3.97)	0.77 (6.38)	0.77 (9.62)
Belgium	0.41 (3.26)	-0.84 (-0.7)	0.5 (5.04)	0.96 (13.18)	1.42 (4.4)
Brazil	1.2 (11.22)	-0.31 (-0.32)	0.42 (1.21)	0.33 (1.35)	0.39 (1.51)
Bulgaria	0.14 (0.59)	0.48 (0.96)	0.58 (2.49)	0.22 (3.68)	0.32 (0.9)
Canada	0.84 (13.98)	-0.67 (-1.37)	0.36 (3.03)	0.55 (11.78)	0.37 (2.16)
China (Mainland)	1.12 (4.92)	0.01 (0.03)	0.11 (0.35)	0.16 (0.71)	0.36 (0.65)
Czech Republic	0.88 (3.42)	0.13 (0.42)	0.15 (1.74)	0.18 (1.79)	0.11 (0.25)
Denmark	0.68 (6.32)	0.2 (0.3)	0.84 (1.89)	0.76 (5.77)	0.96 (3.5)
Estonia	0.85 (6.87)	0.43 (1.65)	0.03 (1.67)	0.19 (2.37)	0.26 (1.23)
Finland	1.6 (6)	0.24 (0.63)	0.62 (4.25)	0.68 (6.41)	0.98 (5.57)
France	1.11 (9.81)	0.45 (2.39)	0.76 (4.25)	0.81 (7.77)	0.72 (6.58)
Germany	1.69 (9.5)	0.59 (1.92)	1.05 (3.2)	0.63 (4.33)	0.37 (1.31)
Greece	0.69 (3.31)	0.93 (1.85)	1.04 (1.82)	0.23 (2.08)	1.03 (1.94)
Hungary	1.21 (6.21)	1.72 (3.18)	0.22 (0.59)	0.16 (0.2)	0.41 (1.67)
India	0.97 (4.62)	-1.06 (-3.68)	0.4 (0.86)	0.63 (2.05)	0.22 (0.65)
Indonesia	0.89 (3.22)	0.31 (0.6)	0.02 (0.07)	0.51 (1.03)	0.29 (0.5)
Ireland	0.55 (3.79)	0.59 (1.81)	0.58 (2.45)	0.89 (11.35)	1.63 (2.49)
Italy	1.03 (7.59)	0.66 (2.63)	1.36 (4.79)	0.56 (3.79)	0.99 (2.94)
Japan	0.53 (5.61)	0.26 (0.88)	0.61 (2.7)	0.19 (5.26)	0.56 (4.05)
Korea	1.19 (6.35)	0.3 (0.7)	0.4 (1.2)	0.41 (1.61)	0.13 (0.44)
Latvia	1.19 (8.78)	-0.13 (-0.35)	-0.02 (-0.07)	0.74 (1.71)	1.59 (3.74)
Malaysia	0.36 (2.57)	-0.04 (-0.13)	0.25 (0.84)	0.09 (1.46)	1.07 (3.64)
Netherlands	0.77 (10.5)	0.26 (0.81)	0.31 (1.33)	0.89 (11.99)	0.91 (4.13)
Norway	0.71 (6.17)	0.14 (0.88)	0.64 (3.47)	1.04 (3.63)	0.59 (2.17)
Poland	1.02 (4.3)	0.84 (2.86)	0.41 (1.99)	0.29 (1.89)	0.48 (2.29)
Portugal	0.76 (6.03)	-0.03 (-0.2)	-0.04 (-0.96)	0.95 (18.74)	0.33 (1.75)
Russia	1.25 (3.49)	1.02 (0.52)	-0.25 (-0.76)	0.19 (0.48)	0.58 (1.41)
Singapore	1.04 (7.51)	-0.54 (-0.9)	0.33 (1.18)	0.74 (4.05)	0.77 (2.62)
Slovak Republic	0.38 (2.49)	0.8 (1.17)	0.13 (1.2)	0.01 (0.06)	1.58 (3.09)
Slovenia	0.09 (0.78)	0.47 (1.4)	0.03 (0.13)	0.22 (1.42)	1.45 (8.42)
South Africa	0.71 (4.32)	-0.69 (-1.44)	0.44 (2.3)	0.36 (2.02)	0.94 (2.61)
Spain	1.02 (7.17)	1.11 (3.91)	0.43 (0.92)	0.65 (5.81)	1.21 (6.24)
Sweden	1.66 (9.75)	1.25 (2.64)	0.7 (2.73)	0.72 (4.06)	1.1 (5.68)
Switzerland	0.41 (4.88)	0.43 (1.72)	0.27 (2.49)	0.61 (3.17)	0.86 (3.8)
Thailand	1.12 (4.81)	-0.99 (-1.14)	0.34 (0.95)	0.51 (1.27)	0.61 (1.79)
Turkey	2.05 (6.19)	-0.49 (-1.08)	-0.49 (-1.32)	4.39 (1.38)	0.73 (1.56)
United Kingdom	0.61 (10.99)	0.33 (1.35)	0.77 (2.93)	0.95 (5.14)	0.12 (0.51)
United States	1.2 (13.28)	0.19 (1.26)	0.28 (1.48)	1.41 (3.95)	-

Note: White's heteroscedastic-robust t-statistics in parenthesis.

Table C.7: Number of cointegrating relations for different weighting schemes

	trade-based weights			mixed weights		
	begin	middle	end	begin	middle	end
Argentina	3	3	2	3	3	2
Australia	2	1	1	2	2	2
Austria	1	1	1	1	1	1
Belgium	2	2	2	2	2	2
Brazil	1	1	1	1	1	1
Bulgaria	1	2	2	2	2	2
Canada	2	2	2	2	2	2
China (Mainland)	5	5	5	5	5	5
Czech Republic	3	3	3	3	3	3
Denmark	2	2	2	2	2	2
Estonia	4	4	4	4	4	4
Finland	4	4	4	4	3	4
France	2	2	2	2	2	2
Germany	2	1	1	2	1	1
Greece	3	3	3	4	3	3
Hungary	3	3	3	3	3	3
India	2	2	2	2	2	2
Indonesia	4	2	2	4	2	2
Ireland	2	2	1	2	1	2
Italy	3	3	3	3	3	3
Japan	0	0	0	1	1	0
Korea	1	1	1	1	1	1
Latvia	1	1	1	1	1	1
Malaysia	3	3	4	3	3	3
Netherlands	3	3	2	3	3	3
Norway	2	2	2	2	2	2
Poland	4	3	3	4	3	3
Portugal	3	2	2	2	2	2
Russia	1	1	2	1	1	1
Singapore	2	1	1	2	2	2
Slovak Republic	2	2	2	2	2	2
Slovenia	4	4	4	4	4	4
South Africa	3	3	3	3	3	2
Spain	1	2	2	1	1	2
Sweden	2	2	2	2	2	2
Switzerland	1	1	1	1	2	1
Thailand	1	2	2	2	2	2
Turkey	3	3	3	3	3	3
United Kingdom	1	0	1	2	1	1
United States	2	2	2	1	2	2

Note: Number of cointegrating relations as indicated by Johansen procedure using critical values from MacKinnon et al. (1999).

Table C.8: GFEVD: a negative standard error unit shock to US real equity prices

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
Developed Markets Americas	eq	11.92	6.82	2.85	1.44	0.87	0.84	1.05	1.18	20.59	14.32	8.64	5.51	4.36	4.95	5.99	6.46
	credit	1.31	2.36	3.04	3.50	3.73	3.67	3.57	3.55	1.67	3.18	4.74	5.61	5.75	5.11	4.49	4.24
	house	1.51	0.87	0.54	0.46	0.35	0.20	0.14	0.12	0.44	0.18	0.14	0.22	0.34	0.69	1.11	1.25
	ibk	0.26	0.51	1.02	1.38	1.69	2.00	2.34	2.49	0.04	0.37	0.71	0.94	1.14	1.32	1.42	1.44
	gdp	0.58	0.70	0.80	0.75	0.69	0.70	0.74	0.76	0.02	0.07	0.22	0.33	0.39	0.44	0.50	0.52
	DMA Vars	15.57	11.27	8.25	7.54	7.32	7.40	7.84	8.10	22.75	18.12	14.44	12.61	11.98	12.51	13.50	13.91
Developed Markets Europe	eq	16.62	17.36	16.70	16.24	15.69	14.81	13.59	12.98	7.22	7.79	9.01	9.25	8.74	7.64	6.71	6.32
	credit	5.24	7.73	9.11	9.35	9.37	9.46	9.63	9.72	4.54	4.14	4.46	5.04	5.64	6.13	6.34	6.40
	house	6.71	7.79	8.19	8.31	8.25	7.91	7.49	7.31	6.71	6.76	6.97	6.85	6.38	5.70	5.24	5.08
	ibk	5.58	4.27	4.36	3.50	2.61	2.13	2.10	2.09	5.51	7.84	6.02	5.23	4.88	4.59	4.14	3.82
	gdp	3.00	7.04	9.67	10.79	11.78	12.85	13.82	14.24	3.17	4.44	6.04	7.09	7.95	8.75	9.41	9.70
	DME Vars	37.14	44.19	48.03	48.19	47.70	47.15	46.62	46.34	27.15	30.96	32.48	33.47	33.60	32.83	31.84	31.31
Developed Markets Pacific	eq	1.81	1.41	1.32	1.34	1.39	1.40	1.35	1.33	0.12	0.37	1.11	1.68	1.96	1.94	1.84	1.80
	credit	2.30	1.67	2.06	2.40	2.70	2.89	2.97	3.00	1.00	1.39	2.35	3.04	3.44	3.45	3.31	3.27
	house	1.93	1.22	0.89	0.88	0.89	0.88	0.86	0.86	0.64	0.80	0.57	0.41	0.46	0.62	0.68	0.70
	ibk	0.98	0.80	0.91	0.93	0.96	1.02	1.07	1.08	1.20	0.91	0.97	0.95	0.89	0.80	0.74	0.72
	gdp	1.21	0.65	0.51	0.63	0.81	0.96	1.08	1.13	2.36	2.35	1.55	0.98	0.65	0.54	0.54	0.55
	DMP Vars	8.23	5.75	5.69	6.18	6.75	7.15	7.33	7.40	5.32	5.81	6.56	7.08	7.41	7.36	7.11	7.04
Developed Markets Total		60.94	61.21	61.96	61.91	61.78	61.70	61.79	61.84	55.22	54.90	53.48	53.16	52.99	52.69	52.44	52.27
Emerging Markets Americas	eq	0.65	1.22	2.06	2.32	2.49	2.53	2.48	2.46	0.47	1.36	3.18	4.13	4.75	5.16	5.37	5.48
	credit	2.28	2.24	1.95	1.90	1.95	2.04	2.07	2.09	2.05	2.81	3.50	3.77	3.86	3.94	3.97	3.98
	house	3.53	2.94	2.54	2.43	2.41	2.52	2.72	2.82	3.67	3.36	3.05	2.86	2.85	3.10	3.41	3.54
	ibk	1.50	2.13	2.76	2.86	2.75	2.57	2.46	2.42	1.91	2.99	2.92	2.58	2.11	1.76	1.60	1.55
	gdp	1.17	1.97	2.35	2.54	2.80	3.03	3.12	3.14	1.78	1.60	1.71	1.96	2.33	2.62	2.74	2.79
	EMAM Vars	9.14	10.50	11.65	12.05	12.40	12.69	12.84	12.92	9.88	12.12	14.36	15.30	15.91	16.58	17.10	17.35
Emerging Markets EMEA	eq	2.69	2.63	3.03	3.60	4.08	4.07	3.69	3.49	1.85	2.50	3.89	5.23	6.19	6.02	5.38	5.12
	credit	3.33	2.45	2.09	1.94	1.77	1.70	1.74	1.77	2.14	2.29	2.56	2.36	1.91	1.75	1.81	1.83
	house	1.12	1.38	1.77	1.90	1.97	1.98	1.93	1.91	0.57	1.22	1.76	1.90	1.94	2.07	2.18	2.22
	ibk	2.55	2.05	1.49	1.28	1.16	1.14	1.18	1.22	2.46	2.31	2.23	2.00	1.85	1.93	2.11	2.18
	gdp	1.29	1.06	1.25	1.31	1.30	1.41	1.66	1.77	0.63	0.35	0.32	0.41	0.48	0.55	0.62	0.64
	EMEA Vars	10.98	9.57	9.63	10.03	10.28	10.30	10.21	10.15	7.65	8.67	10.76	11.90	12.37	12.32	12.10	11.99
Emerging Markets Asia	eq	0.26	0.18	0.06	0.02	0.02	0.03	0.04	0.05	0.01	0.01	0.00	0.00	0.01	0.03	0.04	0.05
	credit	0.01	0.04	0.18	0.21	0.22	0.23	0.25	0.26	0.22	0.14	0.05	0.04	0.08	0.13	0.16	0.17
	house	0.29	0.67	0.69	0.67	0.66	0.69	0.74	0.76	0.57	1.36	1.81	1.90	1.86	1.79	1.73	1.71
	ibk	0.77	0.31	0.11	0.13	0.20	0.27	0.29	0.28	0.18	0.09	0.40	0.77	1.10	1.27	1.26	1.23
	gdp	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.37	0.19	0.10	0.05	0.02	0.01	0.01	0.01
	EMAS Vars	1.35	1.22	1.06	1.06	1.14	1.28	1.38	1.42	1.35	1.79	2.36	2.76	3.07	3.23	3.20	3.17
Emerging Markets Total		21.47	21.28	22.35	23.14	23.81	24.27	24.44	24.49	18.87	22.58	27.48	29.96	31.34	32.13	32.39	32.51
Frontier Markets	eq	7.63	7.16	5.88	5.40	5.11	4.88	4.67	4.58	7.60	6.89	6.27	5.62	5.06	4.63	4.38	4.32
	credit	1.44	2.68	3.17	3.06	2.80	2.55	2.39	2.31	2.14	2.55	2.78	2.75	2.59	2.38	2.21	2.14
	house	1.26	2.96	3.66	4.05	4.38	4.66	4.85	4.93	1.07	2.27	3.65	4.52	5.08	5.31	5.37	5.41
	ibk	0.51	0.85	1.10	1.13	1.11	1.09	1.10	1.11	1.10	1.64	1.86	1.71	1.50	1.41	1.43	1.46
	gdp	2.37	1.76	1.30	1.11	0.95	0.82	0.74	0.70	1.89	1.07	0.54	0.42	0.40	0.36	0.34	0.32
	FM Vars	13.22	15.42	15.11	14.75	14.34	13.99	13.75	13.65	13.80	14.41	15.09	15.02	14.64	14.10	13.74	13.66
Oil price		4.37	2.10	0.59	0.21	0.07	0.04	0.03	0.03	12.11	8.11	3.95	1.86	1.02	1.07	1.42	1.57

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability. Mixed weights on the left hand side; trade-based weights on the right hand side.

Table C.9: GFEVD: a negative standard error unit shock to US real GDP

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
Developed Markets Americas	eq	0.36	0.58	1.11	1.49	1.43	0.88	0.61	0.61	1.03	1.83	3.51	4.96	5.50	4.11	3.20	3.18
	credit	6.39	6.11	4.75	3.37	2.52	2.73	3.07	3.13	6.58	5.97	4.47	3.30	3.16	4.82	5.51	5.38
	house	0.52	0.55	0.65	0.86	1.40	1.92	1.77	1.61	0.08	0.16	0.32	0.50	0.84	1.06	0.72	0.57
	ibk	0.03	0.17	0.78	1.57	1.92	1.14	0.52	0.36	0.01	0.09	0.63	1.31	1.62	0.89	0.42	0.32
	gdp	25.94	25.62	22.72	18.86	13.17	6.98	4.06	3.59	26.26	25.81	22.65	18.54	13.01	6.18	2.77	2.22
	DMA Vars	33.24	33.04	30.02	26.15	20.44	13.65	10.02	9.30	33.96	33.86	31.58	28.62	24.13	17.05	12.61	11.68
Developed Markets Europe	eq	6.15	5.43	5.37	6.04	8.44	12.78	14.95	15.08	5.90	5.41	5.11	5.16	6.03	8.09	8.60	8.40
	credit	6.02	6.15	6.48	6.41	6.03	6.02	6.59	6.89	5.78	5.81	5.94	5.93	5.82	5.86	6.28	6.52
	house	4.00	4.20	4.35	4.67	5.51	6.85	7.42	7.41	3.73	3.71	3.61	3.65	3.96	4.86	5.31	5.35
	ibk	7.14	6.48	8.13	10.78	12.34	9.79	6.37	5.26	6.71	5.93	6.72	7.99	6.94	3.78	3.42	3.38
	gdp	8.95	9.31	9.12	8.14	7.27	8.24	10.50	11.62	9.76	9.48	8.70	7.75	7.27	7.94	9.21	9.95
	DME Vars	32.26	31.56	33.46	36.05	39.58	43.68	45.83	46.27	31.88	30.34	30.07	30.48	30.01	30.52	32.82	33.59
Developed Markets Pacific	eq	0.07	0.09	0.21	0.43	0.85	1.35	1.56	1.60	0.17	0.22	0.34	0.55	1.13	2.20	2.65	2.70
	credit	2.35	2.04	1.86	1.91	2.12	2.35	2.45	2.47	1.26	1.27	1.25	1.33	1.76	2.67	3.14	3.20
	house	0.44	0.46	0.65	0.93	1.25	1.34	1.26	1.21	0.82	0.83	1.10	1.34	1.33	0.95	0.86	0.91
	ibk	0.58	0.54	0.74	0.99	1.10	0.91	0.73	0.68	0.39	0.42	0.67	1.01	1.42	1.51	1.27	1.16
	gdp	0.81	0.88	0.77	0.58	0.33	0.22	0.30	0.33	0.64	0.73	0.71	0.73	0.79	0.80	0.70	0.65
	DMP Vars	4.25	4.01	4.23	4.84	5.65	6.17	6.30	6.28	3.27	3.47	4.07	4.96	6.43	8.13	8.61	8.62
Developed Markets Total		69.76	68.61	67.70	67.04	65.67	63.51	62.15	61.85	69.11	67.67	65.72	64.06	60.58	55.71	54.04	53.89
Emerging Markets Americas	eq	1.40	1.48	1.91	2.39	3.07	3.45	3.33	3.22	1.37	1.50	2.04	2.60	3.21	3.63	3.82	3.86
	credit	1.38	1.28	1.10	0.93	0.84	1.07	1.38	1.47	0.99	0.92	0.84	0.84	1.18	2.17	2.89	3.03
	house	1.07	1.37	1.30	1.21	1.36	1.81	2.19	2.32	1.05	1.08	0.92	0.87	1.06	1.65	2.20	2.40
	ibk	1.03	1.56	2.41	3.10	3.76	4.00	3.83	3.76	1.25	1.45	1.76	2.05	2.31	2.33	2.11	2.03
	gdp	6.39	6.23	5.61	4.74	3.61	2.97	3.13	3.31	6.96	6.94	6.61	5.99	5.27	4.49	4.28	4.40
	EMAM Vars	11.26	11.91	12.32	12.36	12.65	13.30	13.86	14.09	11.62	11.88	12.18	12.35	13.02	14.27	15.31	15.72
Emerging Markets EMEA	eq	0.79	0.70	0.65	0.74	1.35	2.89	3.82	3.91	0.83	0.63	0.58	0.87	2.18	5.11	6.48	6.50
	credit	1.58	1.53	1.43	1.32	1.12	0.93	0.88	0.87	0.57	0.53	0.43	0.34	0.32	0.47	0.58	0.59
	house	1.33	1.29	1.17	1.19	1.35	1.61	1.71	1.67	1.20	1.10	0.83	0.65	0.55	0.82	1.17	1.25
	ibk	1.31	1.19	1.09	1.00	0.97	1.02	1.10	1.15	1.50	1.41	1.37	1.36	1.49	1.68	1.80	1.88
	gdp	5.00	4.23	3.57	3.29	2.86	1.83	1.03	0.82	4.78	4.64	4.42	4.14	3.60	2.32	1.36	1.16
	EMEA Vars	10.02	8.94	7.90	7.53	7.64	8.28	8.54	8.41	8.87	8.32	7.64	7.36	8.13	10.39	11.39	11.38
Emerging Markets Asia	eq	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	credit	0.01	0.00	0.04	0.07	0.10	0.13	0.15	0.16	0.00	0.00	0.01	0.01	0.02	0.03	0.07	0.08
	house	0.02	0.01	0.01	0.00	0.01	0.06	0.13	0.15	0.01	0.00	0.00	0.01	0.08	0.43	0.70	0.72
	ibk	0.02	0.05	0.19	0.36	0.58	0.75	0.85	0.88	0.05	0.12	0.32	0.56	1.04	1.73	2.06	2.10
	gdp	0.46	0.56	0.55	0.48	0.36	0.24	0.20	0.20	0.34	0.44	0.43	0.36	0.23	0.08	0.02	0.01
	EMAS Vars	0.51	0.62	0.80	0.93	1.06	1.19	1.33	1.39	0.41	0.57	0.76	0.94	1.36	2.28	2.85	2.92
Emerging Markets Total		21.79	21.47	21.02	20.82	21.35	22.77	23.72	23.89	20.90	20.77	20.58	20.65	22.52	26.94	29.54	30.02
Frontier Markets	eq	2.00	2.42	2.86	3.14	3.68	4.55	5.06	5.18	1.96	2.47	3.41	4.27	5.29	5.80	5.39	5.20
	credit	0.54	0.66	0.99	1.45	2.28	3.02	3.01	2.89	0.79	0.93	1.22	1.61	2.38	3.29	3.33	3.22
	house	1.20	1.63	2.00	2.27	2.62	3.15	3.68	3.88	1.72	2.09	2.58	2.96	3.47	4.21	4.71	4.85
	ibk	1.08	1.61	1.95	1.95	1.80	1.59	1.49	1.52	1.41	1.74	1.89	1.88	1.80	1.59	1.37	1.32
	gdp	2.78	2.55	2.22	1.83	1.15	0.51	0.30	0.26	2.53	2.49	2.40	2.09	1.58	0.97	0.64	0.56
	FM Vars	7.60	8.87	10.02	10.64	11.52	12.81	13.55	13.73	8.41	9.73	11.51	12.81	14.52	15.86	15.43	15.15
Oil price		0.85	1.05	1.26	1.50	1.46	0.91	0.58	0.54	1.58	1.83	2.20	2.48	2.39	1.49	0.98	0.95

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability. Mixed weights on the left hand side; trade-based weights on the right hand side.

Table C.10: GFEVD: a negative standard error unit shock to US interest rate

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
Developed Markets Americas	eq	0.39	0.22	0.12	0.07	0.07	0.09	0.07	0.06	0.20	0.23	0.29	0.35	0.37	0.46	0.70	0.80
	credit	0.59	0.93	1.26	1.44	1.59	1.96	2.19	2.19	0.84	1.12	1.42	1.92	3.58	5.32	5.38	5.16
	house	0.85	0.52	0.57	0.93	1.80	2.36	2.14	2.01	1.09	0.73	0.81	1.34	2.23	1.94	1.23	1.04
	ibk	24.67	19.61	17.69	15.26	10.61	5.14	2.59	2.05	25.64	21.55	20.35	17.51	9.90	3.03	1.15	0.82
	gdp	0.28	0.10	0.04	0.06	0.18	0.29	0.31	0.30	0.27	0.11	0.06	0.09	0.23	0.29	0.21	0.17
	DMA Vars	26.78	21.38	19.68	17.76	14.23	9.83	7.30	6.60	28.04	23.74	22.93	21.20	16.31	11.03	8.66	7.99
Developed Markets Europe	eq	10.29	8.72	8.97	10.18	13.43	17.68	19.56	19.89	8.58	7.64	8.19	9.68	12.27	12.74	11.60	11.16
	credit	5.61	4.96	4.58	4.00	3.32	3.61	4.44	4.72	5.54	4.72	4.58	4.67	5.03	5.68	6.30	6.54
	house	5.90	5.42	5.46	5.68	6.48	7.79	8.37	8.45	4.64	4.20	4.33	4.71	5.87	6.84	6.83	6.82
	ibk	19.58	30.06	31.54	30.77	26.05	16.92	10.61	8.87	28.19	35.30	33.73	27.52	14.58	6.60	5.65	5.43
	gdp	2.55	2.02	1.77	1.69	2.11	4.06	6.35	7.23	2.90	2.43	2.24	2.35	3.47	5.64	7.38	8.11
	DME Vars	43.93	51.17	52.33	52.32	51.40	50.07	49.33	49.16	49.84	54.29	53.07	48.92	41.23	37.50	37.77	38.06
Developed Markets Pacific	eq	0.94	0.89	1.00	1.19	1.54	1.90	2.07	2.13	0.95	0.93	1.14	1.71	2.87	3.45	3.41	3.41
	credit	1.37	1.20	1.26	1.43	1.79	2.22	2.51	2.62	1.02	0.99	1.25	1.88	3.12	3.89	4.04	4.09
	house	1.56	1.60	1.74	1.85	1.92	1.85	1.73	1.69	0.85	0.96	0.87	0.65	0.36	0.36	0.51	0.58
	ibk	2.77	2.03	1.86	1.69	1.27	0.76	0.53	0.46	1.58	1.82	2.11	2.44	2.44	1.81	1.39	1.28
	gdp	1.38	0.76	0.61	0.54	0.49	0.55	0.65	0.68	0.87	0.70	0.85	1.00	1.07	0.95	0.81	0.77
	DMP Vars	8.02	6.48	6.47	6.69	7.03	7.29	7.48	7.58	5.26	5.40	6.23	7.68	9.86	10.45	10.15	10.12
Developed Markets Total		78.73	79.03	78.48	76.77	72.66	67.19	64.11	63.34	83.14	83.43	82.22	77.81	67.41	58.99	56.58	56.17
Emerging Markets Americas	eq	1.44	1.57	1.91	2.32	2.79	3.02	2.97	2.91	1.46	1.45	1.69	1.94	2.32	2.87	3.31	3.43
	credit	0.52	0.39	0.34	0.35	0.53	1.00	1.41	1.54	0.37	0.33	0.44	0.87	1.99	3.08	3.53	3.62
	house	1.65	1.25	1.22	1.33	1.54	1.74	1.89	1.94	1.28	0.87	0.72	0.77	1.07	1.53	1.93	2.08
	ibk	1.21	3.39	3.63	3.68	3.58	3.30	3.06	2.99	1.24	2.68	2.61	2.38	2.00	1.71	1.55	1.51
	gdp	1.19	0.71	0.48	0.36	0.53	1.29	2.00	2.23	1.25	0.87	0.62	0.50	0.89	1.85	2.57	2.83
	EMAM Vars	6.01	7.31	7.59	8.04	8.96	10.35	11.32	11.60	5.60	6.20	6.08	6.46	8.27	11.04	12.89	13.46
Emerging Markets EMEA	eq	0.63	0.70	0.79	1.17	2.48	4.50	5.56	5.76	0.44	0.43	0.69	1.83	5.14	7.90	8.22	8.09
	credit	2.62	1.81	1.48	1.26	1.04	0.93	0.94	0.95	2.09	1.38	1.17	1.15	1.14	0.97	0.85	0.81
	house	0.64	0.97	1.16	1.41	1.90	2.47	2.73	2.79	0.25	0.43	0.58	0.81	1.34	1.90	2.14	2.21
	ibk	0.63	0.50	0.47	0.50	0.60	0.68	0.71	0.72	0.44	0.37	0.52	0.94	1.51	1.69	1.75	1.80
	gdp	1.32	1.69	2.10	2.49	2.67	2.21	1.68	1.52	1.33	1.45	1.81	2.25	2.42	1.78	1.26	1.11
	EMEA Vars	5.84	5.66	6.00	6.84	8.69	10.78	11.61	11.75	4.55	4.05	4.77	6.97	11.54	14.25	14.22	14.02
Emerging Markets Asia	eq	0.41	0.26	0.24	0.24	0.21	0.12	0.06	0.05	0.24	0.18	0.21	0.25	0.21	0.10	0.04	0.03
	credit	0.16	0.07	0.04	0.03	0.04	0.07	0.10	0.11	0.13	0.05	0.02	0.01	0.01	0.02	0.05	0.06
	house	0.03	0.01	0.01	0.01	0.04	0.13	0.23	0.26	0.02	0.01	0.03	0.15	0.53	0.97	1.11	1.10
	ibk	0.00	0.07	0.11	0.17	0.27	0.41	0.52	0.56	0.00	0.06	0.15	0.39	0.98	1.56	1.82	1.87
	gdp	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.07	0.06	0.05	0.05
	EMAS Vars	0.61	0.43	0.42	0.47	0.58	0.74	0.92	0.98	0.40	0.31	0.44	0.85	1.79	2.71	3.08	3.11
Emerging Markets Total		12.45	13.40	14.01	15.35	18.24	21.87	23.85	24.33	10.55	10.57	11.29	14.27	21.61	28.00	30.18	30.60
Frontier Markets	eq	0.89	0.44	0.30	0.35	0.92	2.18	3.04	3.24	0.47	0.59	0.82	1.32	2.56	3.58	3.72	3.70
	credit	3.69	3.59	3.84	4.33	4.95	4.90	4.44	4.28	2.18	2.36	2.74	3.46	4.39	4.27	3.79	3.63
	house	2.20	2.05	2.06	2.07	2.19	2.68	3.24	3.45	2.09	1.87	1.90	2.10	2.82	3.81	4.39	4.57
	ibk	0.76	0.46	0.38	0.38	0.48	0.63	0.75	0.80	0.47	0.28	0.22	0.22	0.35	0.56	0.67	0.70
	gdp	1.15	0.90	0.74	0.59	0.49	0.52	0.57	0.56	1.11	0.87	0.75	0.74	0.84	0.79	0.63	0.57
	FM Vars	8.70	7.44	7.33	7.72	9.02	10.92	12.03	12.33	6.31	5.98	6.41	7.84	10.96	13.01	13.20	13.17
Oil price		0.12	0.13	0.18	0.16	0.08	0.02	0.01	0.01	0.00	0.02	0.07	0.07	0.03	0.01	0.04	0.06

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability. Mixed weights on the left hand side; trade-based weights on the right hand side.

Table C.11: GFEVD with different weighting schemes: a negative standard error unit shock to US real equity prices

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
		mixed weights - beginning of sample								trade-based weights - beginning of sample							
Developed Markets	eq	24.50	19.87	16.14	13.48	11.04	9.23	8.13	7.83	31.69	25.24	19.64	16.63	14.94	16.59	17.95	18.77
	credit	6.24	8.85	10.58	10.89	10.46	9.73	9.12	8.94	6.31	9.24	12.68	14.33	14.63	12.95	11.83	10.96
	house	7.48	7.23	7.22	7.02	6.61	6.22	5.99	5.96	6.19	6.55	7.10	7.12	6.98	8.76	9.25	9.55
	ibk	9.43	13.32	17.53	23.39	30.71	36.96	40.81	41.62	3.18	5.28	6.30	7.37	7.92	7.14	7.20	6.57
	gdp	6.41	7.37	7.17	6.43	5.62	5.08	4.97	5.08	4.69	6.65	8.43	9.13	9.52	9.68	9.50	9.52
	DM Vars	54.07	56.64	58.65	61.21	64.44	67.22	69.02	69.44	52.07	52.97	54.15	54.58	53.98	55.12	55.73	55.38
Emerging Markets	eq	2.77	3.52	4.60	4.93	4.81	4.46	4.13	4.02	1.94	3.90	6.40	7.78	8.86	8.55	8.07	8.00
	credit	4.57	4.17	4.13	3.92	3.61	3.36	3.20	3.18	4.78	5.02	5.18	5.13	5.10	5.03	5.06	5.19
	house	3.19	4.55	5.47	5.68	5.56	5.33	5.15	5.10	3.53	4.99	6.09	6.62	7.15	7.15	6.84	6.87
	ibk	5.55	5.83	6.02	5.98	5.79	5.59	5.42	5.37	3.92	4.85	5.12	4.97	4.52	3.86	3.77	3.62
	gdp	2.46	2.41	2.85	3.15	3.26	3.21	3.12	3.10	1.92	1.99	2.30	2.46	2.45	2.63	2.73	2.70
	EM Vars	18.54	20.47	23.07	23.67	23.04	21.94	21.02	20.76	16.09	20.76	25.09	26.97	28.08	27.21	26.47	26.38
Frontier Markets	eq	8.06	7.12	5.98	5.03	4.15	3.51	3.10	3.00	8.28	7.07	6.03	5.55	5.39	4.93	4.79	4.83
	credit	2.32	3.12	3.31	3.04	2.61	2.21	1.94	1.86	3.25	3.47	3.34	3.02	2.56	2.12	2.01	1.87
	house	0.60	1.43	2.01	2.21	2.25	2.28	2.35	2.42	0.52	1.88	3.25	4.22	5.19	5.07	4.54	4.45
	ibk	0.75	1.36	1.45	1.24	1.01	0.89	0.87	0.90	0.34	0.94	1.38	1.44	1.42	1.32	1.41	1.48
	gdp	3.09	2.36	1.57	1.16	0.86	0.66	0.54	0.50	1.50	1.45	1.15	0.97	0.75	0.70	0.68	0.60
	FM Vars	14.81	15.40	14.32	12.68	10.88	9.53	8.80	8.67	13.90	14.80	15.16	15.20	15.31	14.14	13.44	13.22
Oil price		12.58	7.49	3.96	2.45	1.65	1.30	1.15	1.14	17.95	11.48	5.59	3.25	2.63	3.53	4.36	5.02
		mixed weights - end of sample								trade-based weights - end of sample							
Developed Markets	eq	20.05	18.27	18.07	17.50	16.63	15.62	14.75	14.38	23.29	20.36	18.67	17.67	16.55	15.17	14.11	13.57
	credit	6.20	8.09	10.51	11.96	12.92	13.39	13.58	13.61	6.80	8.91	11.20	12.85	13.90	14.22	14.36	14.41
	house	11.56	10.28	8.96	7.92	6.97	6.28	5.88	5.77	9.83	9.66	8.92	8.10	7.43	7.23	7.43	7.64
	ibk	14.23	14.99	11.99	11.46	12.59	14.52	16.13	16.71	8.19	9.54	9.06	8.82	9.42	11.15	13.06	14.08
	gdp	7.74	8.86	9.65	9.88	9.86	9.74	9.68	9.70	6.30	7.50	8.36	8.86	9.25	9.39	9.34	9.30
	DM Vars	59.78	60.49	59.18	58.73	58.96	59.54	60.02	60.17	54.41	55.98	56.21	56.30	56.55	57.16	58.30	59.00
Emerging Markets	eq	5.44	6.34	8.89	10.28	10.95	11.08	11.02	10.98	3.75	5.44	8.74	11.06	12.30	12.34	12.13	11.98
	credit	2.18	2.96	3.67	3.87	3.85	3.78	3.71	3.67	5.29	5.79	5.87	5.48	5.03	4.85	4.67	4.54
	house	6.08	5.55	4.81	4.29	3.94	3.77	3.70	3.69	6.30	6.36	5.81	5.22	4.88	4.80	4.62	4.50
	ibk	5.55	5.16	4.57	4.20	3.90	3.76	3.71	3.70	5.05	5.10	5.05	4.88	4.72	4.71	4.65	4.58
	gdp	2.32	2.26	2.55	2.94	3.34	3.58	3.69	3.72	2.80	2.61	2.70	2.94	3.24	3.45	3.57	3.64
	EM Vars	21.57	22.28	24.49	25.58	25.98	25.96	25.83	25.76	23.19	25.30	28.17	29.59	30.16	30.15	29.63	29.24
Frontier Markets	eq	6.26	5.83	5.55	5.18	4.72	4.29	4.03	3.96	6.82	5.99	5.23	4.72	4.25	3.80	3.46	3.32
	credit	3.06	3.46	3.49	3.33	3.16	2.98	2.83	2.76	2.31	2.59	2.75	2.75	2.72	2.68	2.57	2.48
	house	3.71	4.52	5.09	5.28	5.29	5.20	5.17	5.19	3.28	3.91	4.26	4.41	4.48	4.39	4.20	4.09
	ibk	0.59	0.90	1.13	1.25	1.37	1.50	1.61	1.66	0.93	1.06	1.15	1.15	1.17	1.26	1.33	1.38
	gdp	2.09	1.14	0.62	0.49	0.49	0.51	0.50	0.48	2.36	1.24	0.62	0.46	0.46	0.49	0.48	0.47
	FM Vars	15.70	15.85	15.88	15.54	15.02	14.49	14.15	14.06	15.70	14.79	14.01	13.49	13.08	12.61	12.04	11.75
Oil price		2.95	1.38	0.45	0.15	0.04	0.01	0.01	0.01	6.70	3.94	1.60	0.62	0.21	0.08	0.02	0.01

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability.

Table C.12: GFEVD with different weighting schemes: a negative standard error unit shock to US real GDP

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
		mixed weights - beginning of sample								trade-based weights - beginning of sample							
Developed Markets	eq	5.62	6.17	7.82	9.94	11.24	9.73	8.16	7.65	7.12	7.29	8.57	10.11	12.23	14.26	14.70	14.86
	credit	12.39	11.77	10.73	9.82	9.55	9.55	9.01	8.71	12.22	11.90	10.72	9.64	9.93	12.46	12.14	12.03
	house	5.34	5.18	5.32	5.82	6.23	5.90	5.61	5.50	4.67	4.65	4.93	5.51	6.24	6.36	6.04	5.93
	ibk	9.45	8.67	7.56	7.87	15.48	29.95	38.01	39.56	8.58	7.58	8.73	10.43	8.85	4.82	3.55	3.12
	gdp	37.07	35.98	32.11	25.13	13.78	6.90	5.61	5.77	38.67	38.24	34.04	28.29	20.69	13.55	12.60	12.43
	DM Vars	69.88	67.77	63.54	58.58	56.27	62.05	66.39	67.18	71.28	69.66	66.99	63.97	57.93	51.44	49.03	48.37
Emerging Markets	eq	2.79	3.00	3.62	4.48	5.33	5.00	4.41	4.22	2.57	2.71	3.31	4.09	6.03	9.28	10.23	10.39
	credit	2.22	1.97	1.86	2.10	2.83	3.17	3.11	3.08	1.55	1.38	1.23	1.13	1.40	2.45	2.71	2.74
	house	2.65	2.76	2.94	3.53	4.92	5.50	5.34	5.27	1.91	1.94	1.67	1.55	2.14	4.10	4.83	4.99
	ibk	2.49	2.81	3.80	5.42	7.18	6.83	6.20	6.11	2.33	2.41	2.79	3.41	4.72	5.70	5.60	5.58
	gdp	8.55	8.16	7.26	5.88	3.93	3.09	2.97	2.94	8.85	8.57	8.03	7.37	6.03	4.01	3.52	3.37
	EM Vars	18.70	18.70	19.49	21.41	24.18	23.60	22.02	21.62	17.22	17.00	17.02	17.55	20.31	25.55	26.88	27.07
Frontier Markets	eq	2.41	3.30	4.94	6.65	7.12	5.19	3.93	3.70	2.11	2.77	3.99	5.28	7.19	8.41	8.87	9.07
	credit	0.82	1.04	1.52	2.17	2.82	2.55	2.12	2.00	0.96	1.15	1.58	2.15	3.32	4.09	3.88	3.85
	house	1.89	2.19	2.67	2.95	2.75	2.41	2.39	2.47	2.20	2.62	3.15	3.43	3.61	4.19	4.74	4.87
	ibk	1.21	1.71	2.31	2.67	2.33	1.43	1.10	1.10	1.04	1.50	1.81	1.95	2.08	1.89	1.79	1.81
	gdp	3.27	3.02	2.49	1.75	0.83	0.49	0.40	0.36	2.92	2.70	2.34	1.85	1.19	0.74	0.64	0.61
	FM Vars	9.61	11.26	13.94	16.18	15.85	12.06	9.95	9.62	9.23	10.74	12.87	14.66	17.40	19.32	19.92	20.23
Oil price		1.81	2.27	3.04	3.84	3.70	2.29	1.64	1.58	2.27	2.59	3.11	3.82	4.36	3.70	4.17	4.34
		mixed weights - end of sample								trade-based weights - end of sample							
Developed Markets	eq	5.60	5.31	6.57	8.77	12.77	16.28	16.26	15.79	6.65	7.53	9.93	12.72	15.92	17.78	16.57	15.19
	credit	13.75	13.15	11.83	10.67	10.63	12.32	13.44	13.70	14.81	14.27	12.67	11.26	10.96	12.93	14.64	14.91
	house	5.01	5.51	6.09	6.78	7.70	7.73	6.86	6.51	4.84	4.73	4.63	4.68	4.88	5.43	6.32	6.95
	ibk	10.89	10.00	9.26	10.10	8.96	7.68	10.02	11.21	6.48	6.07	7.38	9.49	9.67	6.80	7.54	9.94
	gdp	33.81	33.80	31.25	26.35	18.94	12.61	10.62	10.37	35.82	34.85	30.77	25.37	19.22	13.79	10.76	9.92
	DM Vars	69.06	67.76	65.01	62.67	59.00	56.60	57.21	57.58	68.60	67.44	65.37	63.53	60.64	56.73	55.83	56.91
Emerging Markets	eq	2.44	2.46	3.38	4.86	8.15	11.61	12.31	12.30	2.24	2.30	3.33	4.98	7.72	11.12	12.61	12.56
	credit	2.40	2.55	2.59	2.58	2.75	3.22	3.46	3.49	1.76	1.64	1.47	1.40	1.66	2.67	3.80	4.14
	house	2.80	2.76	2.32	2.06	2.26	2.96	3.32	3.39	2.82	2.56	2.04	1.69	1.66	2.48	3.58	3.98
	ibk	2.45	2.94	3.97	5.11	6.15	5.73	4.91	4.69	3.74	3.96	4.53	5.13	5.83	6.26	5.88	5.42
	gdp	11.29	11.10	10.76	9.50	6.87	4.30	3.65	3.61	12.01	12.08	11.56	10.34	8.43	6.04	4.50	4.10
	EM Vars	21.38	21.81	23.03	24.11	26.19	27.82	27.65	27.47	22.56	22.54	22.94	23.54	25.29	28.57	30.37	30.20
Frontier Markets	eq	2.37	2.77	3.35	3.90	4.77	5.12	4.73	4.57	1.72	2.19	2.92	3.60	4.33	4.72	4.25	3.82
	credit	1.03	1.09	1.38	1.91	2.96	3.62	3.42	3.26	0.81	0.96	1.30	1.71	2.37	3.09	3.11	2.87
	house	1.96	2.35	2.84	3.22	3.85	4.61	4.92	5.01	2.05	2.22	2.41	2.51	2.71	3.33	3.90	4.00
	ibk	0.86	1.10	1.19	1.15	1.18	1.41	1.63	1.72	1.08	1.29	1.45	1.45	1.38	1.39	1.44	1.46
	gdp	2.54	2.27	2.20	1.91	1.17	0.51	0.37	0.35	1.90	1.89	1.90	1.83	1.63	1.22	0.78	0.62
	FM Vars	8.75	9.58	10.95	12.09	13.93	15.28	15.07	14.91	7.56	8.55	9.99	11.10	12.43	13.76	13.48	12.77
Oil price		0.81	0.86	1.01	1.14	0.88	0.30	0.07	0.03	1.28	1.47	1.70	1.82	1.63	0.94	0.32	0.12

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability.

Table C.13: GFEVD with different weighting schemes: a negative standard error unit shock to US interest rate

	months	0	1	3	6	12	24	48	80	0	1	3	6	12	24	48	80
		mixed weights - beginning of sample								trade-based weights - beginning of sample							
Developed Markets	eq	8.58	9.07	10.49	12.81	16.14	13.43	10.08	9.43	10.22	8.75	9.18	11.41	16.48	17.55	17.32	17.44
	credit	9.21	9.24	9.66	10.37	11.40	10.86	9.62	9.22	8.32	7.54	7.77	8.25	10.74	13.54	13.23	13.18
	house	8.82	8.82	9.15	9.81	9.99	7.51	6.16	5.91	7.12	6.34	6.41	6.99	8.37	8.08	7.58	7.44
	ibk	58.01	56.88	52.09	42.34	22.88	22.79	32.76	34.45	53.10	56.20	54.22	46.40	24.66	10.36	8.50	7.61
	gdp	2.84	2.74	2.77	3.03	4.02	4.87	4.91	5.06	3.79	2.90	2.54	2.60	4.31	6.44	6.65	6.74
	DM Vars	87.47	86.76	84.17	78.36	64.42	59.46	63.54	64.07	82.56	81.73	80.11	75.66	64.55	55.96	53.28	52.42
Emerging Markets	eq	1.35	1.42	1.84	2.81	5.18	5.93	5.09	4.90	1.85	1.95	2.31	3.34	6.67	10.05	11.03	11.27
	credit	1.31	1.18	1.27	1.73	3.09	3.85	3.63	3.61	2.20	1.64	1.38	1.48	2.49	3.53	3.80	3.85
	house	1.48	1.45	1.75	2.51	4.83	6.38	6.08	6.06	1.99	1.72	1.63	1.93	3.54	5.49	6.11	6.32
	ibk	1.63	2.10	2.64	3.66	6.00	6.98	6.49	6.47	2.40	4.05	4.47	5.08	5.77	5.56	5.53	5.51
	gdp	1.61	1.71	2.13	2.84	4.12	4.22	3.70	3.63	2.17	2.20	2.64	3.32	4.03	3.72	3.45	3.40
	EM Vars	7.39	7.87	9.62	13.55	23.21	27.37	24.99	24.67	10.61	11.56	12.42	15.15	22.50	28.36	29.92	30.34
Frontier Markets	eq	0.47	0.62	1.00	1.78	3.64	4.33	3.69	3.54	0.39	0.66	0.94	1.50	3.10	4.65	5.16	5.36
	credit	1.18	1.56	1.99	2.59	3.56	3.17	2.42	2.26	2.73	2.87	3.32	4.32	5.53	5.02	4.79	4.76
	house	1.34	1.42	1.55	1.74	2.23	2.58	2.66	2.80	2.05	1.97	1.94	1.82	2.08	3.44	3.99	4.15
	ibk	0.64	0.60	0.70	0.92	1.29	1.19	1.04	1.08	0.60	0.38	0.37	0.48	0.73	0.87	0.90	0.95
	gdp	1.28	1.06	0.90	0.86	0.90	0.74	0.54	0.46	1.05	0.77	0.65	0.65	0.97	1.05	0.91	0.88
	FM Vars	4.91	5.26	6.15	7.88	11.61	12.01	10.35	10.14	6.81	6.65	7.22	8.77	12.42	15.03	15.76	16.10
Oil price		0.24	0.11	0.07	0.20	0.76	1.17	1.12	1.11	0.02	0.06	0.24	0.42	0.53	0.65	1.04	1.14
		mixed weights - end of sample								trade-based weights - end of sample							
Developed Markets	eq	10.82	9.62	10.20	11.80	15.64	18.84	18.16	17.50	7.74	7.53	8.59	10.74	14.60	16.65	15.62	14.59
	credit	7.36	6.61	6.50	6.69	7.97	11.01	12.92	13.35	6.69	6.15	6.29	7.20	10.01	13.67	14.94	14.99
	house	6.92	6.05	6.18	6.87	8.35	8.71	7.61	7.17	5.99	5.25	5.27	5.74	6.90	7.69	7.76	7.87
	ibk	48.60	53.48	52.79	47.43	31.64	13.39	9.71	9.94	55.72	57.90	55.38	47.68	30.12	13.31	9.94	11.22
	gdp	4.25	3.13	2.72	2.96	4.83	8.06	9.46	9.73	4.15	3.50	3.28	3.46	4.73	7.03	8.46	8.89
	DM Vars	77.95	78.89	78.39	75.75	68.44	60.01	57.85	57.70	80.28	80.32	78.81	74.82	66.37	58.34	56.72	57.56
Emerging Markets	eq	2.34	2.40	3.02	4.38	7.78	11.63	12.59	12.65	3.20	3.18	3.96	5.73	9.51	12.74	13.11	12.72
	credit	3.52	2.45	2.08	1.99	2.31	3.08	3.48	3.54	2.19	1.53	1.35	1.49	2.21	3.48	4.21	4.34
	house	2.13	1.92	2.01	2.30	2.95	3.59	3.72	3.72	1.91	1.73	1.83	2.07	2.76	3.88	4.38	4.41
	ibk	2.15	4.37	4.73	5.07	5.30	4.79	4.25	4.10	2.24	3.63	4.08	4.78	5.51	5.67	5.37	5.06
	gdp	2.99	2.31	2.13	2.14	2.49	3.21	3.65	3.75	3.36	2.89	2.84	2.96	3.14	3.32	3.57	3.68
	EM Vars	13.12	13.44	13.96	15.88	20.82	26.30	27.68	27.76	12.89	12.96	14.07	17.02	23.13	29.08	30.64	30.22
Frontier Markets	eq	0.56	0.34	0.39	0.73	1.88	3.46	3.94	3.99	0.35	0.67	0.99	1.51	2.55	3.41	3.47	3.36
	credit	3.04	3.15	3.47	3.95	4.55	4.40	3.77	3.53	1.77	2.10	2.56	3.19	3.98	4.02	3.38	2.97
	house	2.37	2.04	1.98	2.15	2.91	4.18	4.78	4.93	1.76	1.50	1.46	1.63	2.38	3.58	4.08	4.10
	ibk	0.77	0.53	0.44	0.41	0.52	0.98	1.39	1.54	0.83	0.68	0.61	0.54	0.53	0.77	1.10	1.26
	gdp	2.17	1.59	1.32	1.10	0.86	0.65	0.57	0.54	2.08	1.75	1.50	1.28	1.06	0.78	0.60	0.53
	FM Vars	8.90	7.64	7.60	8.34	10.73	13.68	14.45	14.52	6.80	6.71	7.11	8.16	10.50	12.56	12.63	12.23
Oil price		0.03	0.03	0.04	0.03	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.00	0.01	0.01	0.00	0.00

Note: Percentage of k-step ahead forecast error variance of the historical shock to the US real equity prices. Percentages may not sum up to 100 due to covariances between shocks; they are therefore rescaled for a better readability.

Table C.14: Countries and regions (MSCI)

Developed Markets	Developed Markets Americas	Canada
		United States
	Developed Markets Europe	Austria
		Belgium
		Denmark
		Finland
		France
		Germany
		Greece
		Ireland
		Italy
		Netherlands
		Norway
		Portugal
		Spain
		Sweden
		Switzerland
		United Kingdom
	Developed Markets Pacific	Australia
		Japan
		Singapore
Emerging Markets	Emerging Markets Americas	Brazil
	Emerging Markets EMEA	Czech Republic
		Hungary
		Poland
		Russia
		South Africa
		Turkey
	Emerging Markets Asia	China (Mainland)
		India
		Indonesia
		Korea
		Malaysia
		Thailand
Frontier Markets	Frontier Markets Americas	Argentina
	Frontier Markets CEE	Bulgaria
		Estonia
		Latvia
		Slovak Republic
		Slovenia

Note: Based on MSCI Barra classification.

Table C.15: Countries and regions (IMF)

Asia Pacific	Australia	BRIC	Brazil
	Indonesia		China (Mainland)
	Japan		India
	Korea		Russia
	Malaysia	Eastern Europe	Bulgaria
	Singapore		Czech Republic
	Thailand		Estonia
Euroland	Austria		Hungary
	Belgium		Latvia
	Finland		Poland
	France	US	United States
	Germany	Other Developed Countries	Canada
	Greece		Denmark
	Ireland		Norway
	Italy		Sweden
	Netherlands		Switzerland
	Portugal		United Kingdom
	Slovak Republic	Other Emerging Economies	Argentina
	Slovenia		South Africa
	Spain		Turkey

Note: Based on classification from Galesi and Sgherri (2009).

Table C.16: Monte Carlo results

	known (initial) lag order				unknown lag order			
	$N = 10$		$N = 40$		$N = 10$		$N = 40$	
	model with fixed mixed weights							
	trace	max.eig.	trace	max.eig.	trace	max.eig.	trace	max.eig.
size	0.1050	0.1002	0.1021	0.1745	0.1437	0.1503	0.1129	0.1877
power	0.9572	0.9940	0.9861	0.9825	0.9463	0.9864	0.9656	0.9768
	model with time-varying mixed weights							
	trace	max.eig.	trace	max.eig.	trace	max.eig.	trace	max.eig.
size	0.0438	0.0633	0.0804	0.1791	0.1988	0.2191	0.1420	0.2372
power	1.0000	1.0000	1.0000	0.9482	1.0000	1.0000	1.0000	0.9538
	model with fixed mixed weights and shorter sample							
	trace	max.eig.	trace	max.eig.	trace	max.eig.	trace	max.eig.
size	0.1112	0.0808	0.1332	0.1638	0.1302	0.1108	0.1303	0.1671
power	0.9658	0.9144	0.9944	0.9824	0.9507	0.9039	0.9830	0.9770
	model with fixed trade-based weights							
	trace	max.eig.	trace	max.eig.	trace	max.eig.	trace	max.eig.
size	0.0916	0.0870	0.1142	0.1742	0.1168	0.1192	0.1174	0.1847
power	0.9885	0.9986	0.9931	0.9547	0.9607	0.9905	0.9785	0.9495

Note: Based on 10000 replications for subsets of 10 and 40 countries. Last four columns report results for models in which lag order was determined by AIC in each replication.

Table C.17: Tests of structural change

Test	*eq*	*cc*	*re*	*ir*	*gdp*	*d*	Total	
							Num.	%
PK sup	3	6	4	4	4	0	21	10%
PK msq	3	6	4	10	7	0	30	15%
Nyblom	18	11	15	25	14	1	84	42%
robust Nyblom	16	8	9	22	13	1	69	34%
QLR	15	15	13	28	14	0	85	42%
robust QLR	8	6	6	3	7	1	31	15%
MW	13	14	12	22	16	0	77	38%
robust MW	8	4	4	8	10	1	35	17%
APW	15	13	13	29	14	0	84	42%
robust APW	8	5	5	5	9	1	33	16%

Note: Table display the number of rejections per variable and test as well as the share of rejections over all possible cases. Tests are conducted at 5% level.

Table C.18: Autoregressive distributed lag models

$(i.j)$	EC	LRC		ARDL(p.q1.q2)
(1.2)	0.0717 (0.1789)	1.4921 (0.7273)	−13.1036 (29.9815)	ARDL(3.0.0)
(1.3)	−0.5900 (0.2460)	0.7267 (0.3213)	4.8394 (1.8908)	ARDL(3.0.2)
(2.1)	0.1861 (0.2585)	−7.6282 (9.0522)	1.4897 (0.3070)	ARDL(3.0.0)
(2.3)	−0.3277 (0.1616)	2.6938 (2.9754)	2.7533 (0.6482)	ARDL(1.0.0)
(3.1)	−0.4600 (0.2494)	8.9167 (3.6034)	−0.2744 (0.6518)	ARDL(3.2.2)
(3.2)	−0.7516 (0.1464)	3.3305 (0.2450)	1.4795 (0.8933)	ARDL(3.2.0)

Note: EC denotes error-correcting term, LRC stands for long-run coefficients; last column reports lag order that is chosen according to AIC information criterion; standard errors in brackets take into account super-consistency (T-consistency) of long-run coefficients.

C.2 Figures

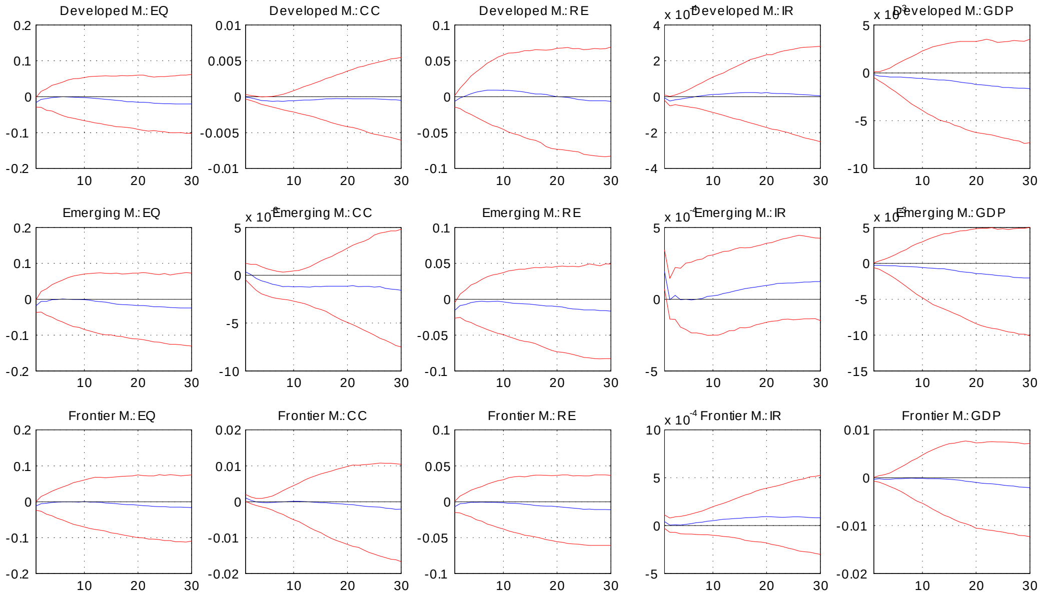

Figure C.1: IRFs to a negative one standard error shock to US equity with 68% confidence bands.

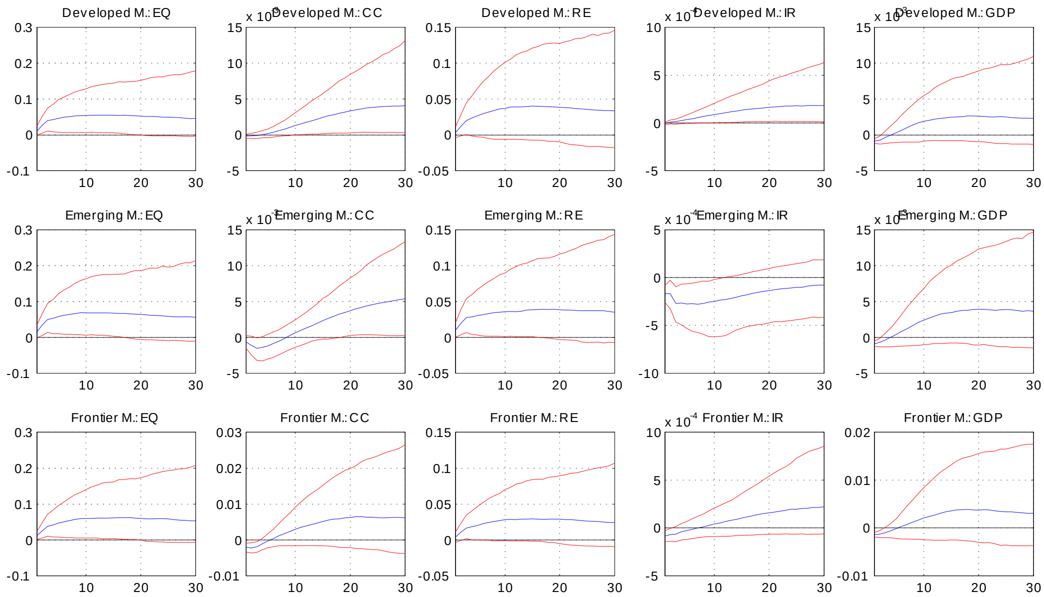

Figure C.2: IRFs to a negative one standard error shock to US GDP with 68% confidence bands.

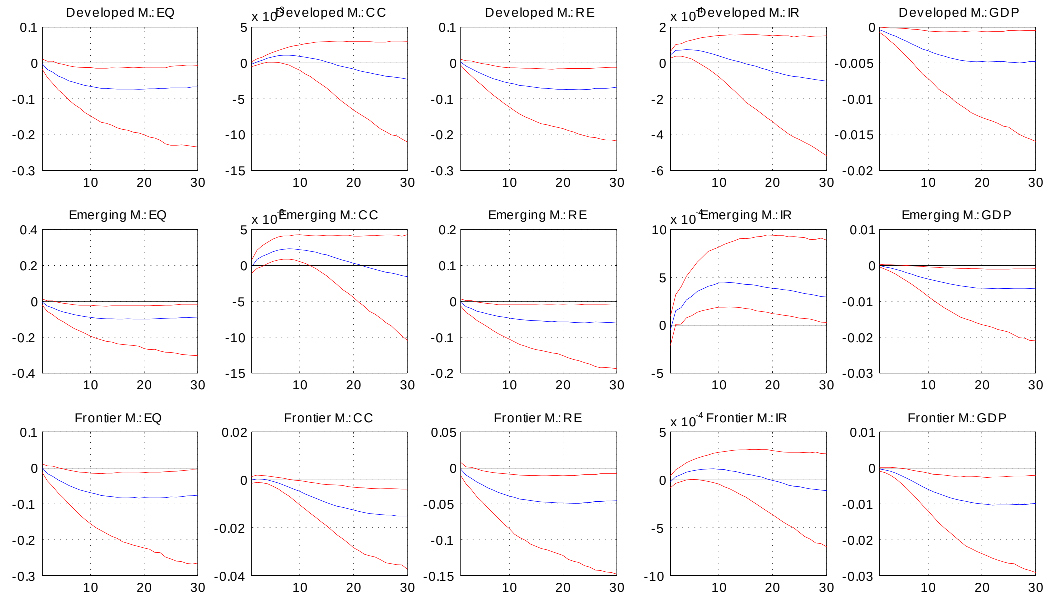

Figure C.3: IRFs to a positive one standard error shock to US interest rate with 68% confidence bands.

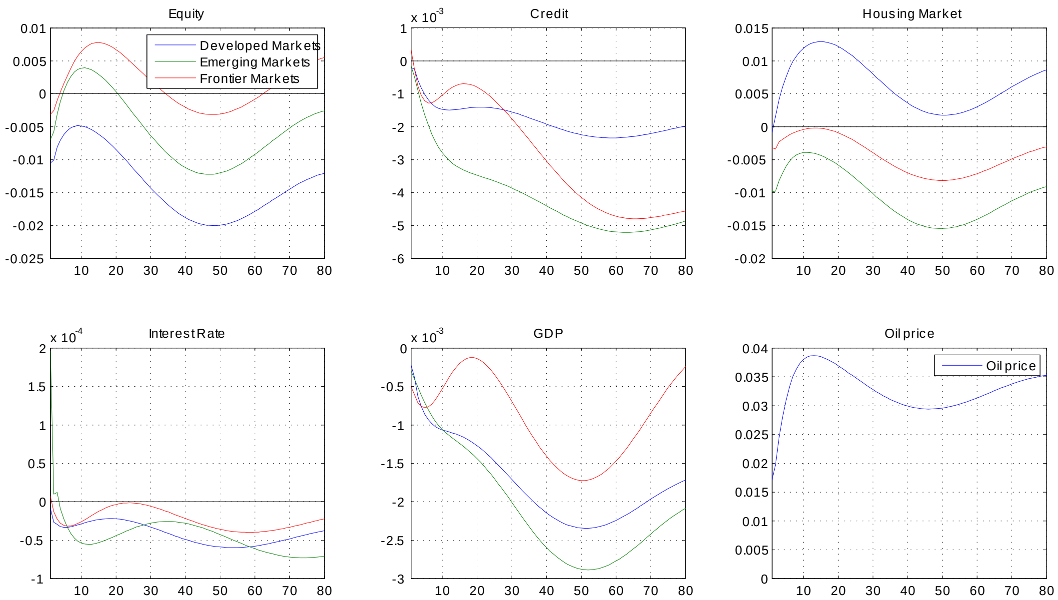

Figure C.4: IRFs to a negative one standard error shock to US equity using mixed weights from the beginning of the sample.

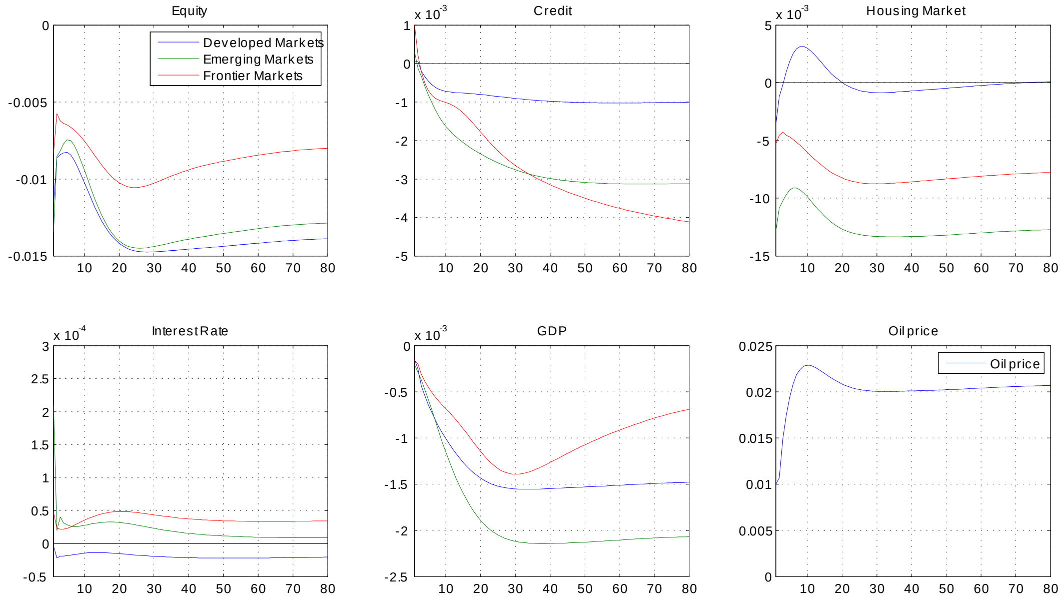

Figure C.5: IRFs to a negative one standard error shock to US equity using mixed weights from the middle of the sample.

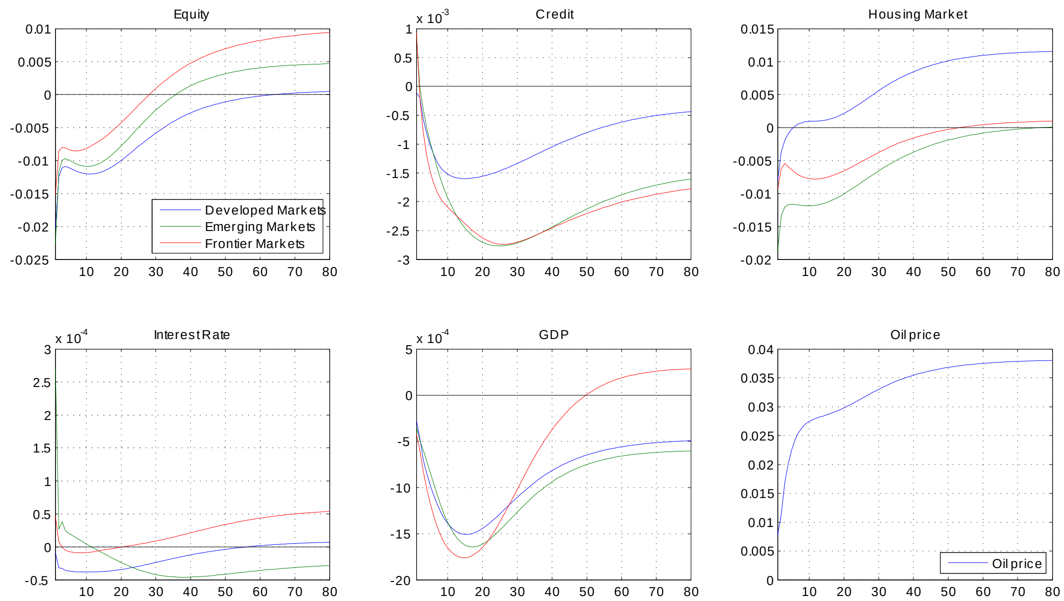

Figure C.6: IRFs to a negative one standard error shock to US equity using mixed weights from the end of the sample.

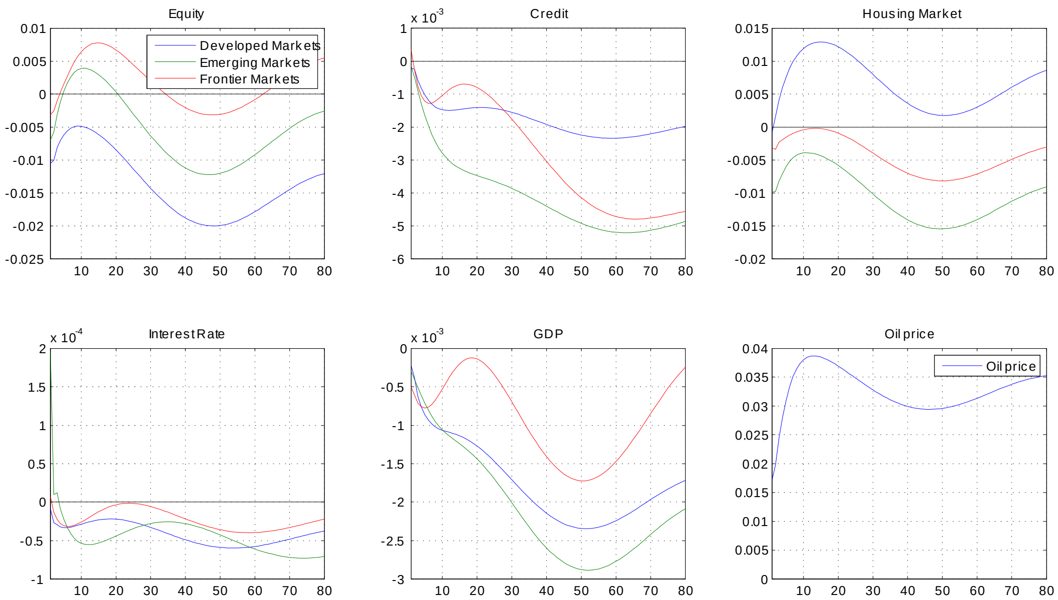

Figure C.7: IRFs to a negative one standard error shock to US equity using trade-based weights from the beginning of the sample.

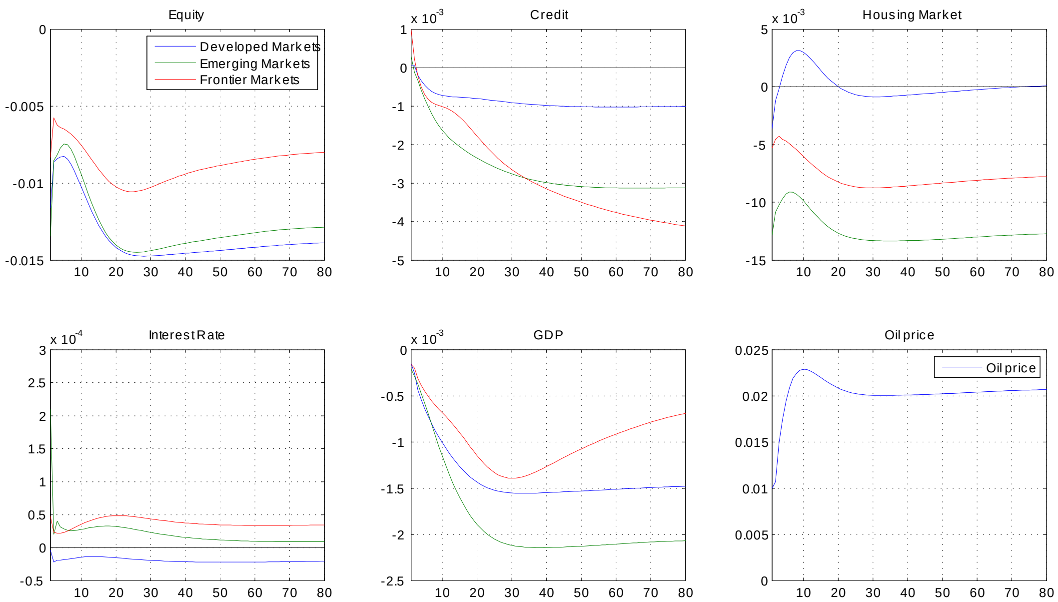

Figure C.8: IRFs to a negative one standard error shock to US equity using trade-based weights from the middle of the sample.

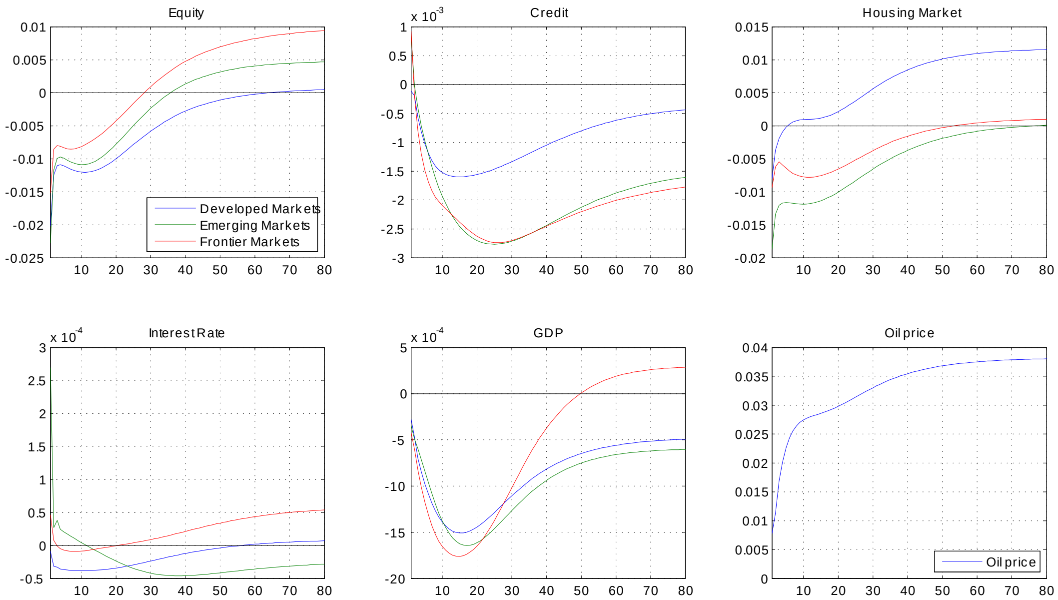

Figure C.9: IRFs to a negative one standard error shock to US equity using trade-based weights from the end of the sample.

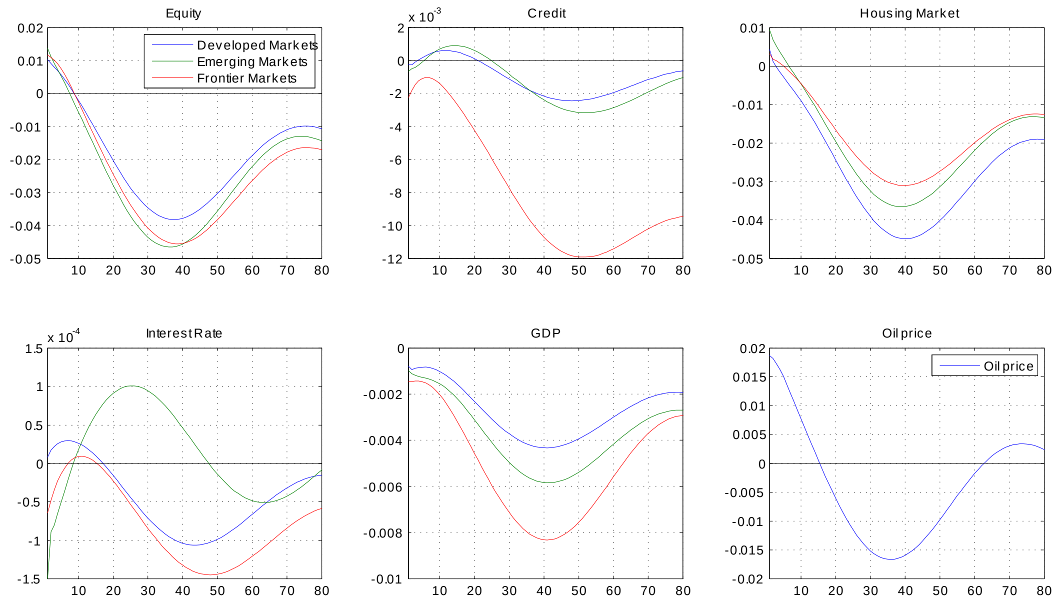

Figure C.10: IRFs to a negative one standard error shock to US real GDP using mixed weights from the beginning of the sample.

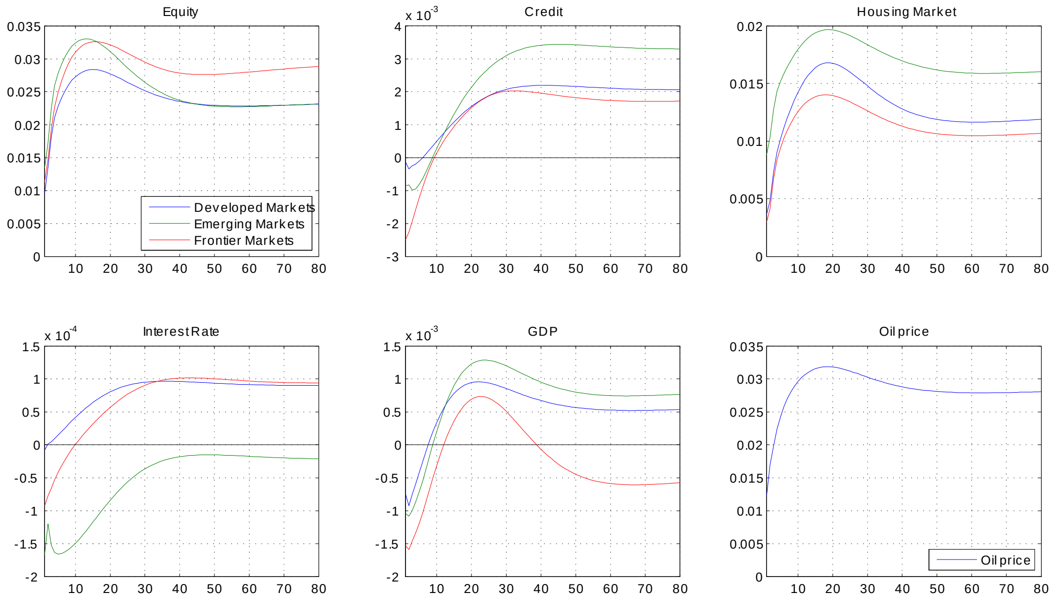

Figure C.11: IRFs to a negative one standard error shock to US real GDP using mixed weights from the middle of the sample.

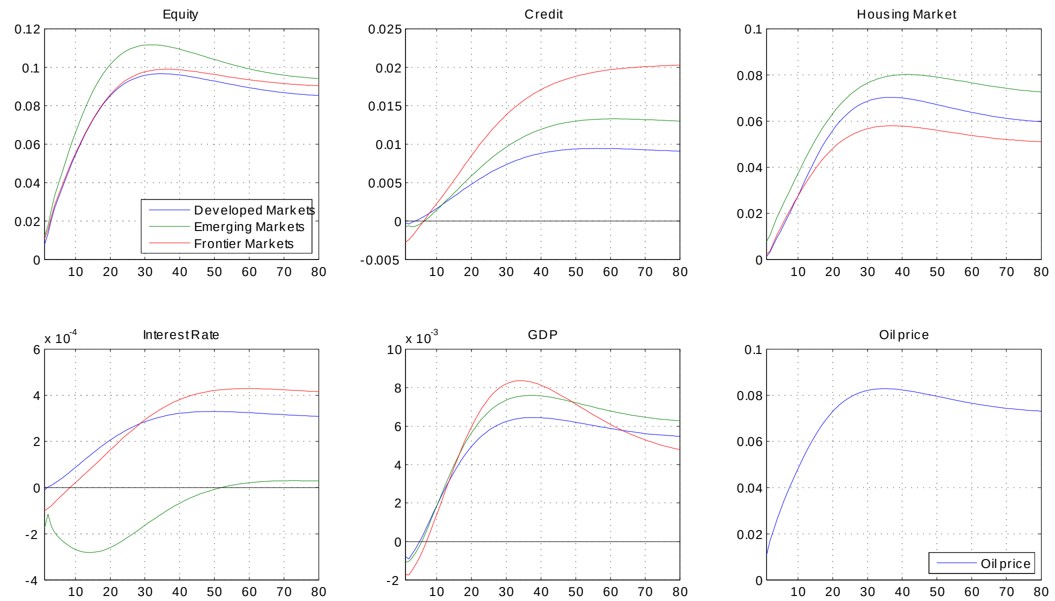

Figure C.12: IRFs to a negative one standard error shock to US real GDP using mixed weights from the end of the sample.

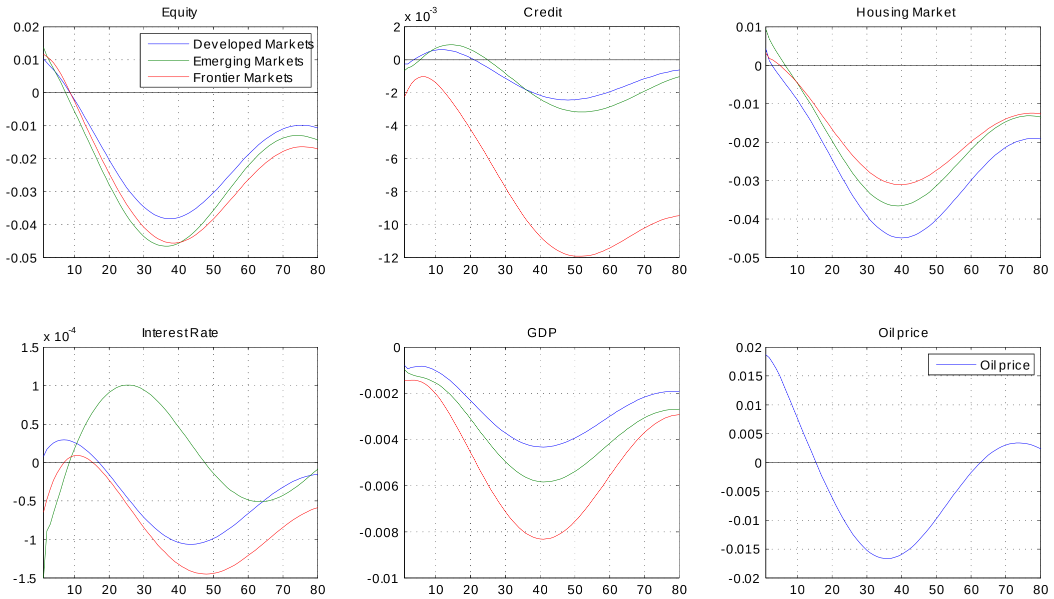

Figure C.13: IRFs to a negative one standard error shock to US real GDP using trade-based weights from the beginning of the sample.

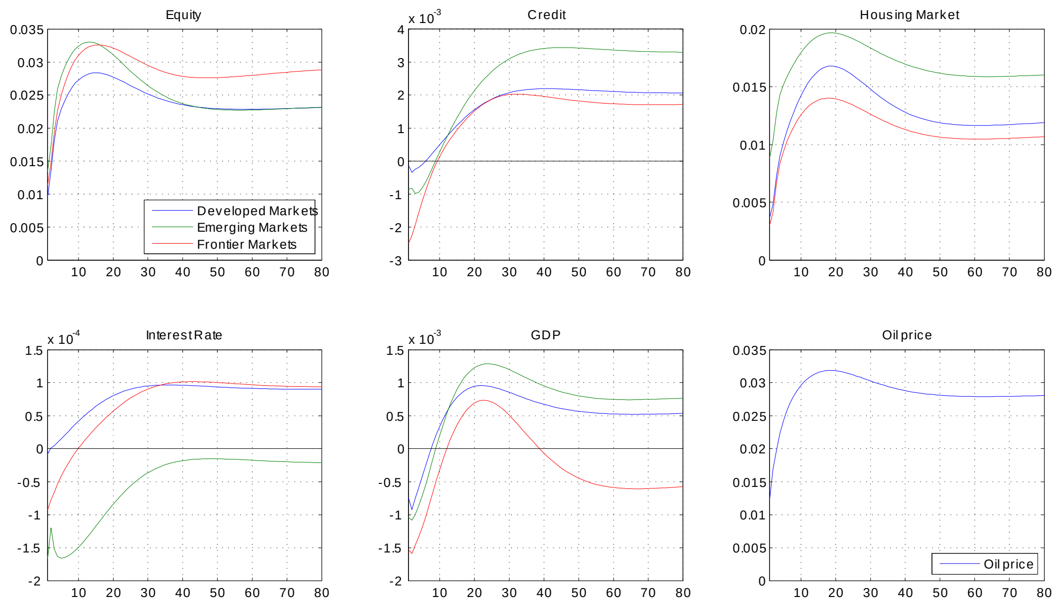

Figure C.14: IRFs to a negative one standard error shock to US real GDP using trade-based weights from the middle of the sample.

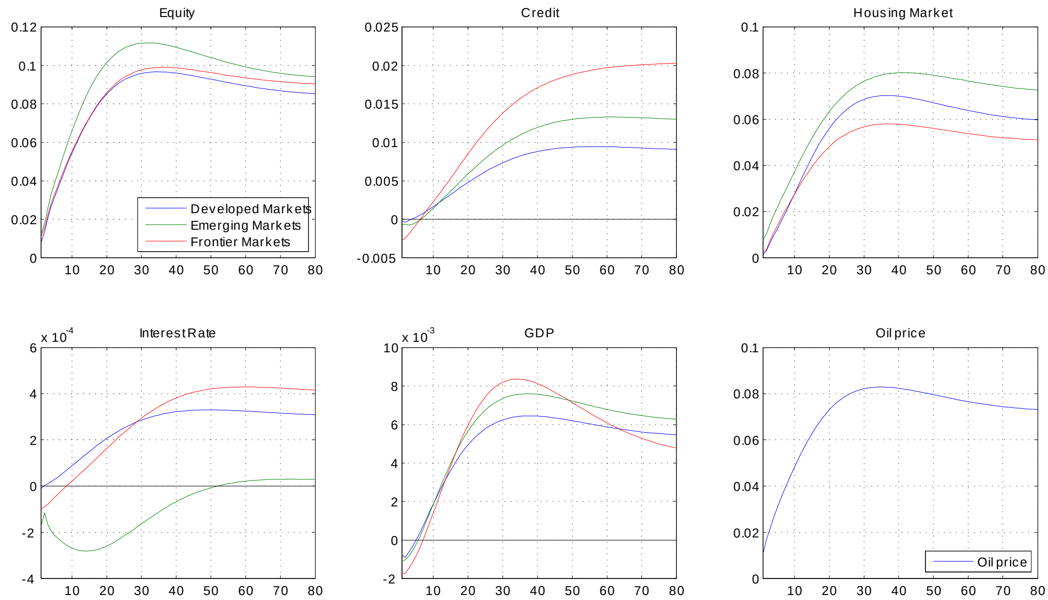

Figure C.15: IRFs to a negative one standard error shock to US real GDP using trade-based weights from the end of the sample.

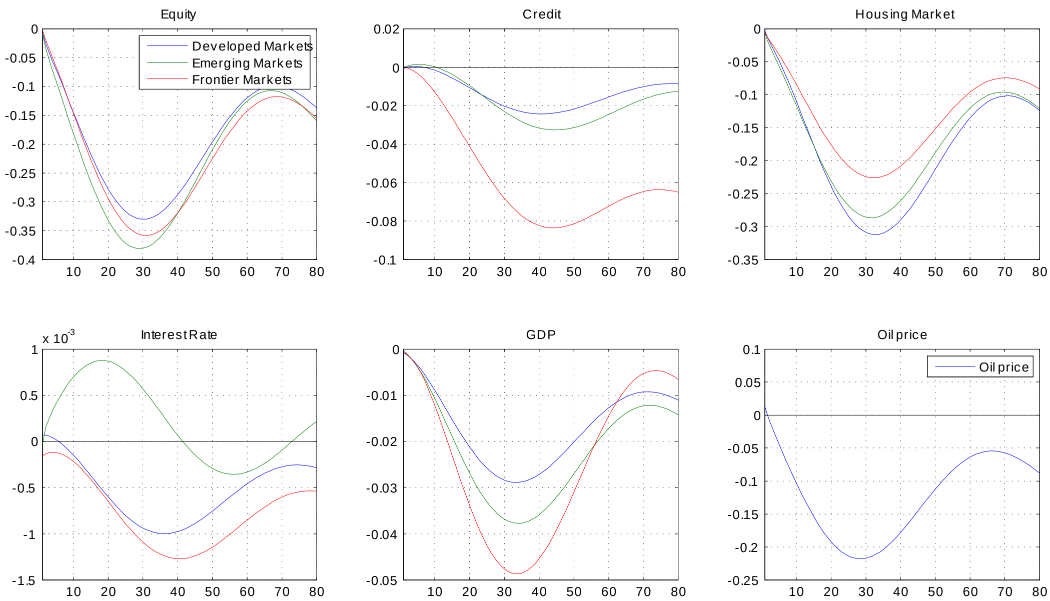

Figure C.16: IRFs to a positive one standard error shock to US interest rate using mixed weights from the beginning of the sample.

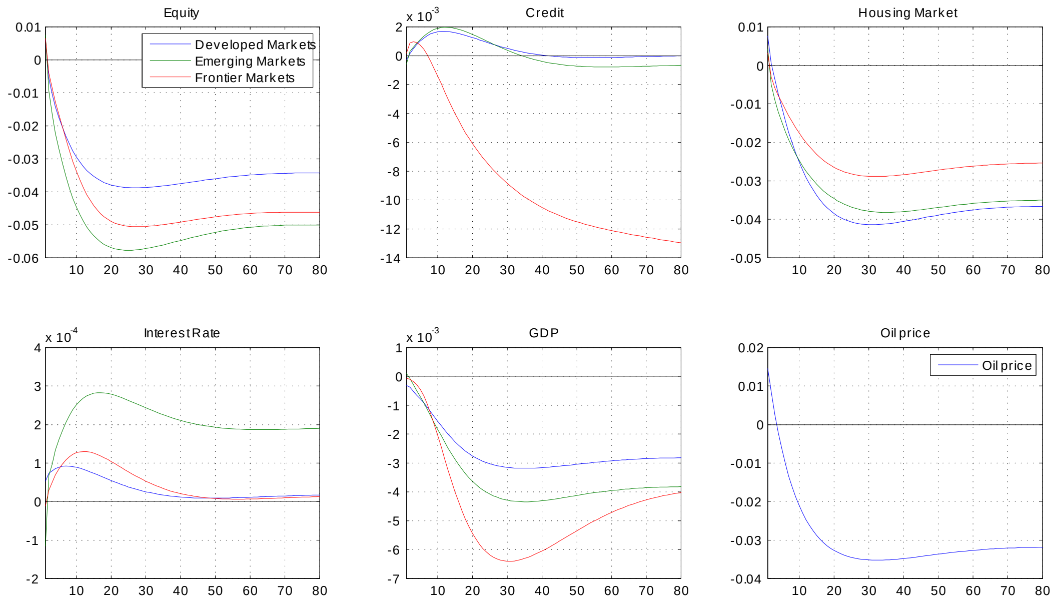

Figure C.17: IRFs to a positive one standard error shock to US interest rate using mixed weights from the middle of the sample.

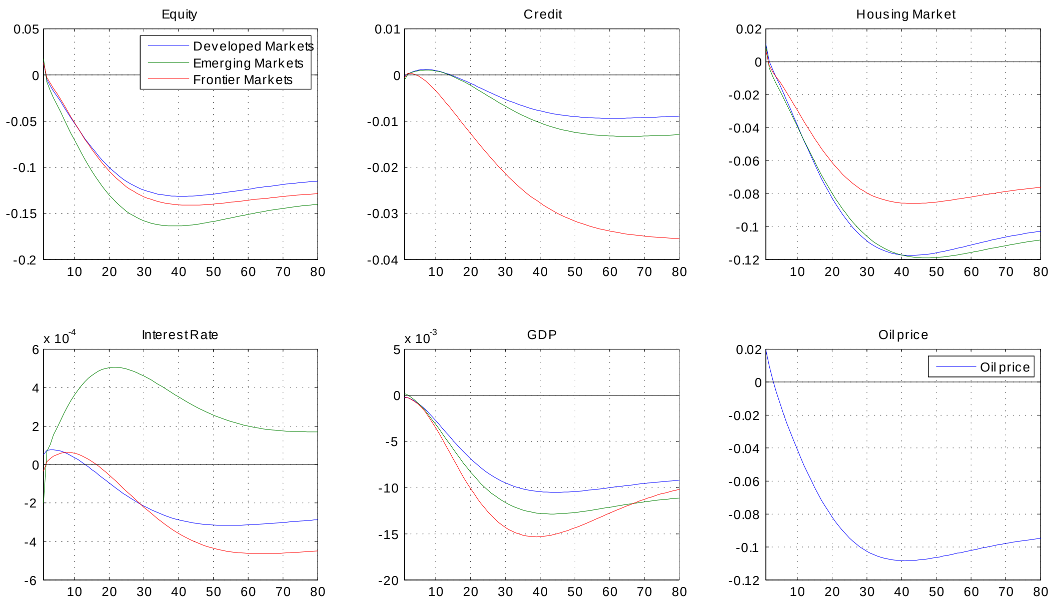

Figure C.18: IRFs to a positive one standard error shock to US interest rate using mixed weights from the end of the sample.

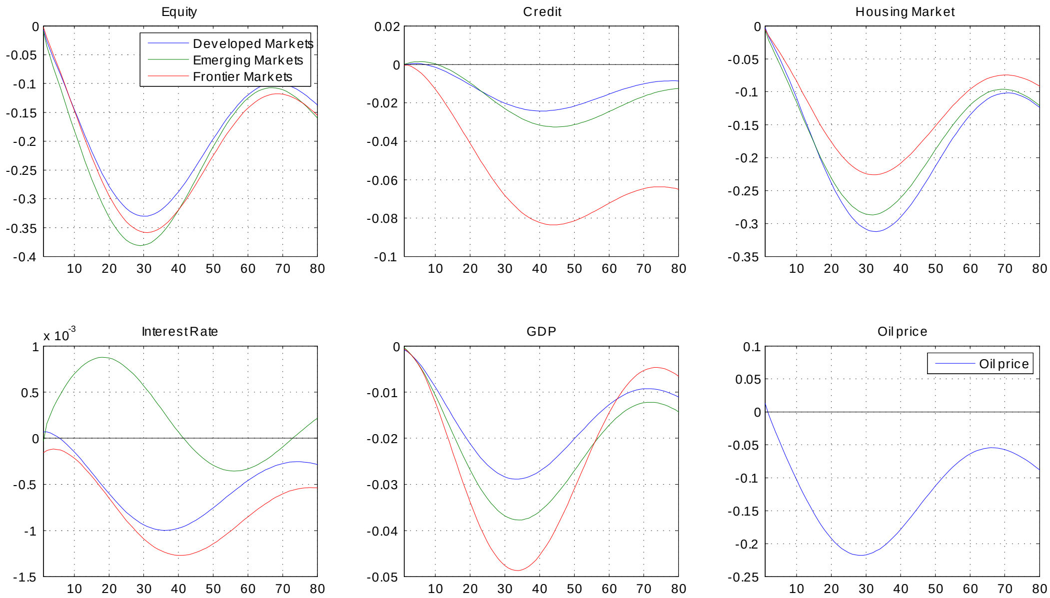

Figure C.19: IRFs to a positive one standard error shock to US interest rate using trade-based weights from the beginning of the sample.

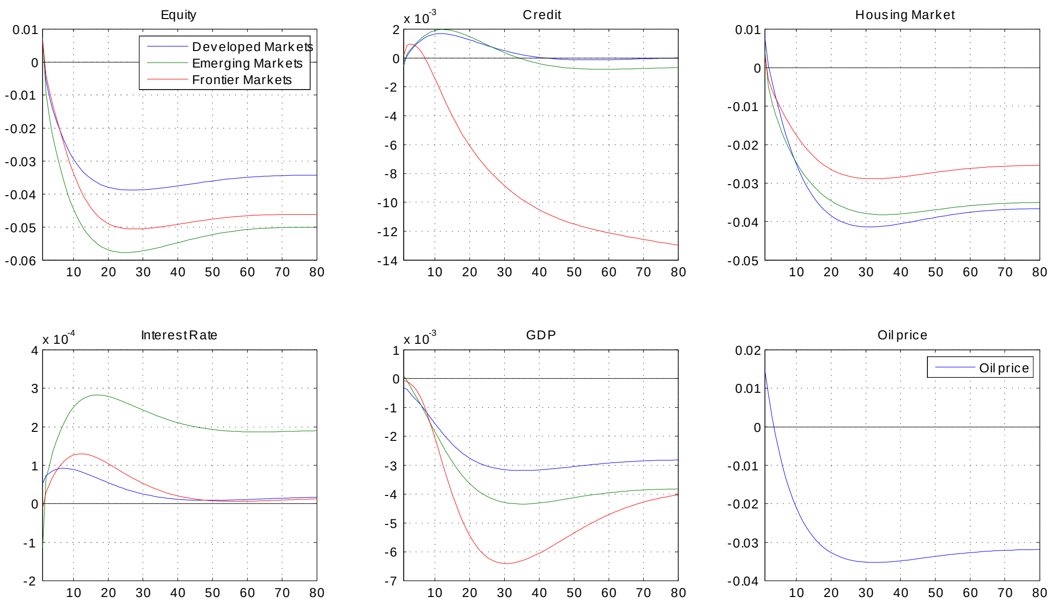

Figure C.20: IRFs to a positive one standard error shock to US interest rate using trade-based weights from the middle of the sample.

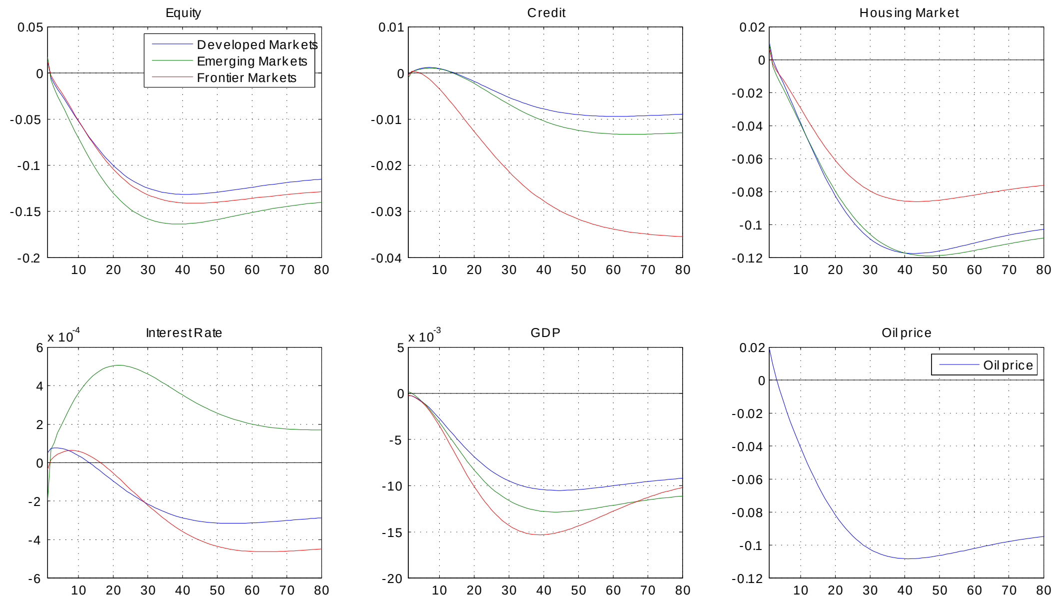

Figure C.21: IRFs to a positive one standard error shock to US interest rate using trade-based weights from the end of the sample.

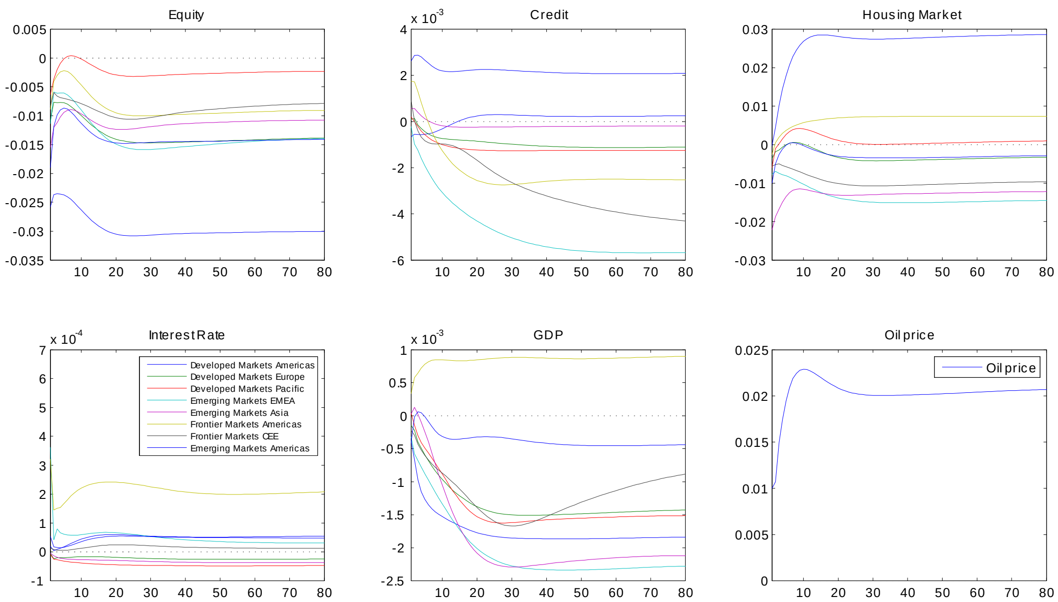

Figure C.22: IRFs to a negative one standard error shock to US equity.

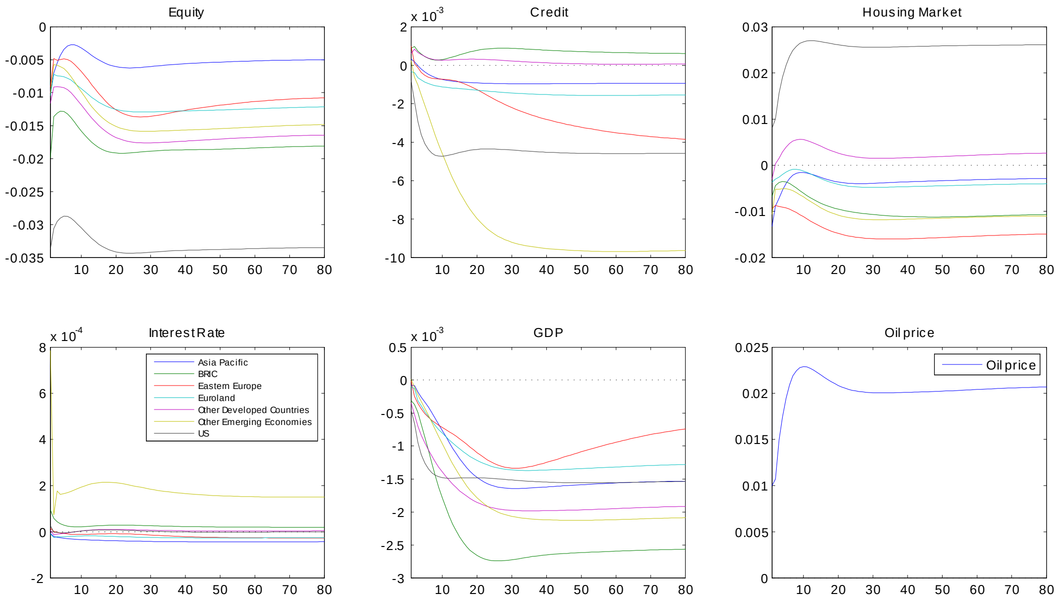

Figure C.23: IRFs to a negative one standard error shock to US equity.

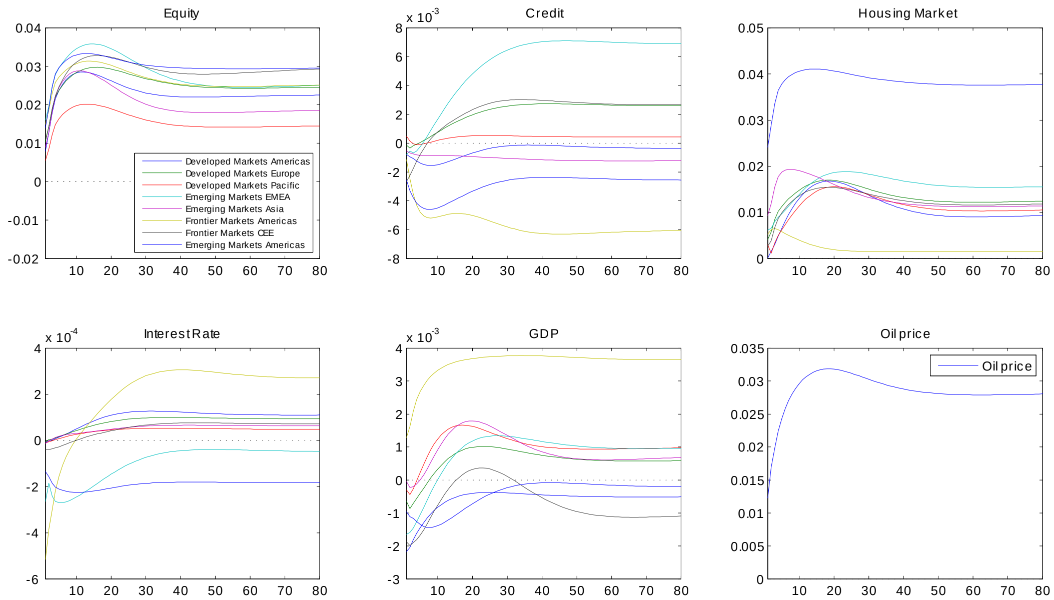

Figure C.24: IRFs to a negative one standard error shock to US real GDP.

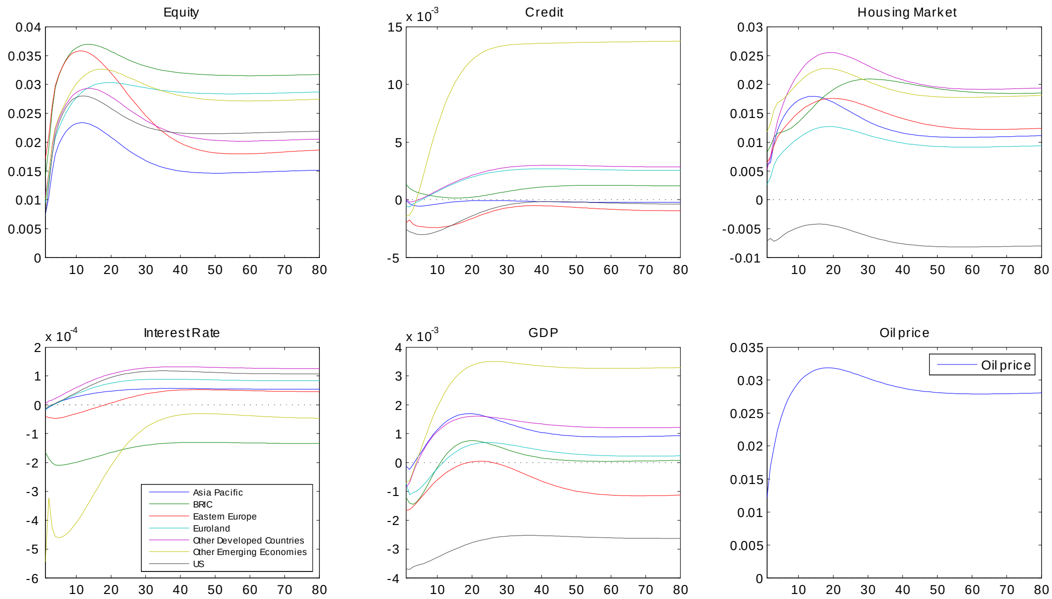

Figure C.25: IRFs to a negative one standard error shock to US real GDP.

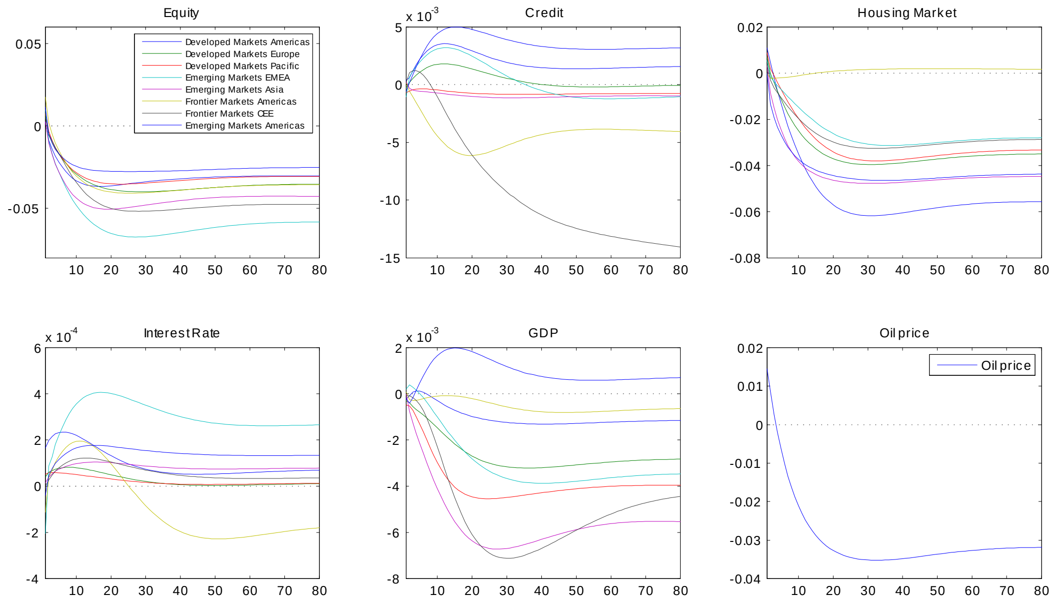

Figure C.26: IRFs to a positive one standard error shock to US interest rate.

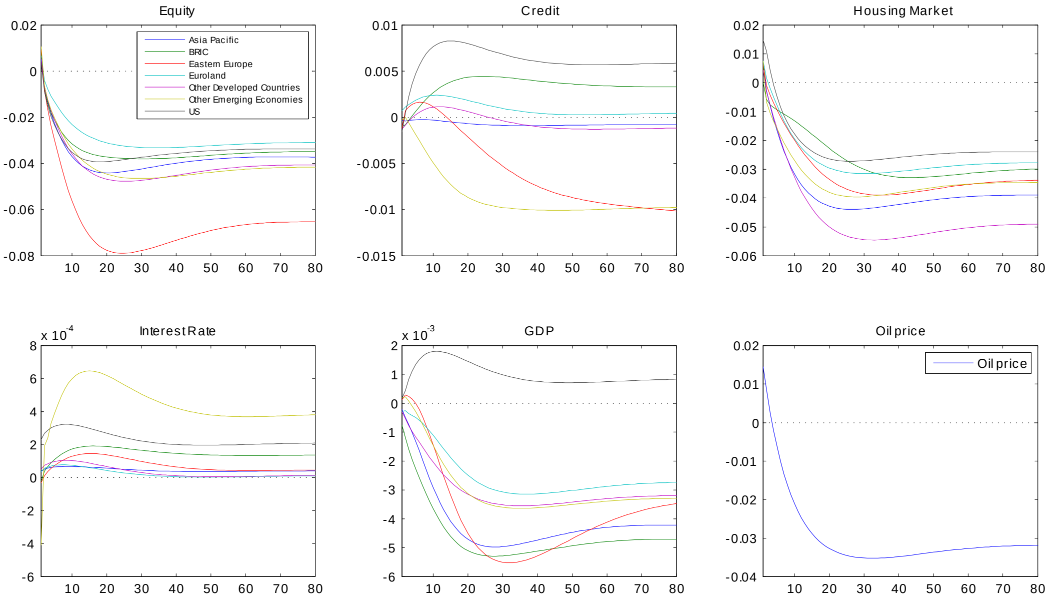

Figure C.27: IRFs to a positive one standard error shock to US interest rate.

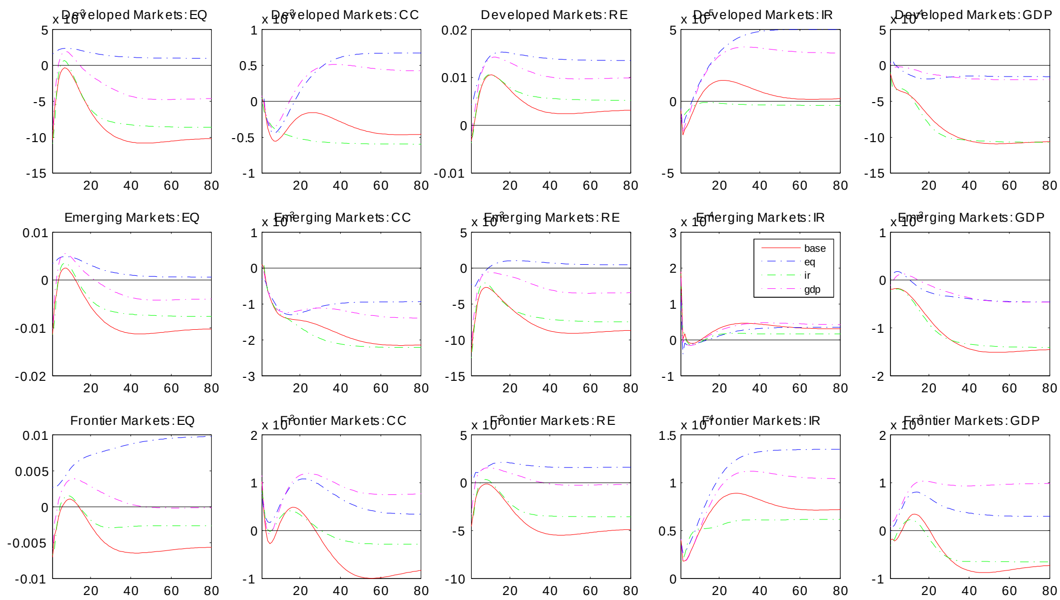

Figure C.28: IRFs to a negative one standard error shock to US equity.

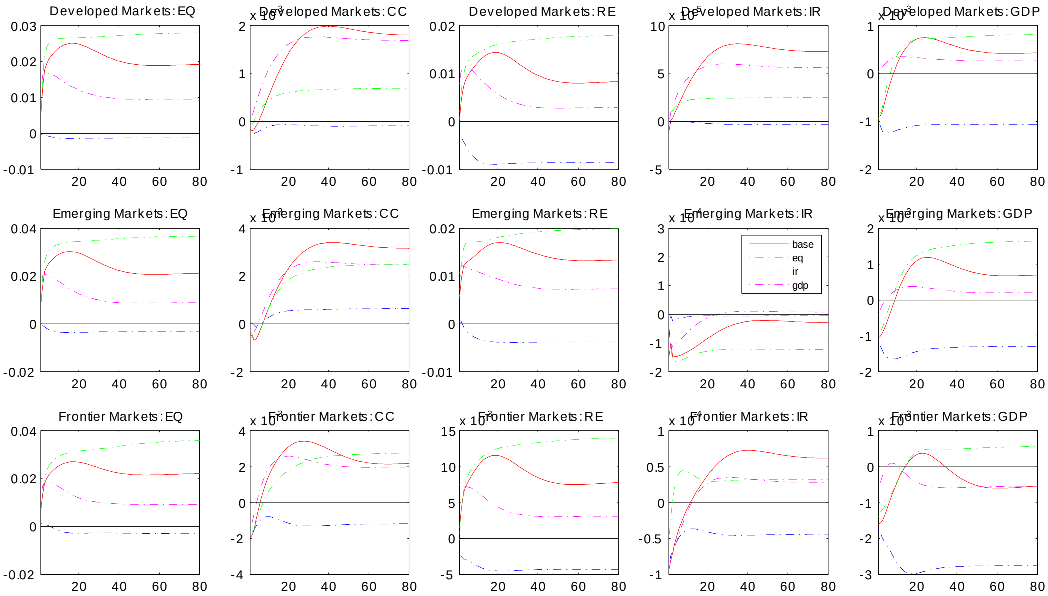

Figure C.29: IRFs to a negative one standard error shock to US real GDP.

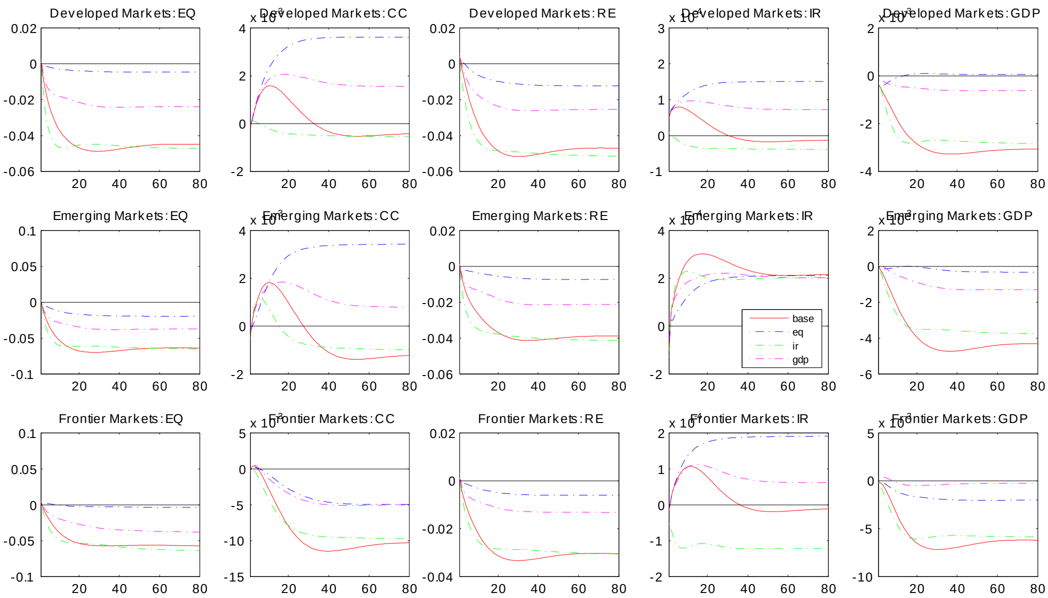

Figure C.30: IRFs to a positive one standard error shock to US interest rate.