Universidad Carlos III de Madrid

Tesis Doctoral

Essays on Business Cycles and Stabilization Policy in a Small Commodity-Exporting Economy

Autor:
Valery Charnavoki

Director:
Juan Jose Dolado

Codirector:
Manuel Santos

Departamento de Economia

Getafe, Noviembre de 2011

TESIS DOCTORAL

Essays on Business Cycles and Stabilization Policy in a Small Commodity-Exporting Economy

Autor: Valery Charnavoki

Director: Juan Jose Dolado

Codirector: Manuel Santos

Firma del Tribunal Calificador:

Firma

Presidente:

Vocal:

Vocal:

Vocal:

Secretario:

Calificacion:

Getafe, de Diciembre de 2011

Contents

Acknowledgments

I am deeply grateful to my advisors Juanjo Dolado and Manuel Santos for their guidance and help. This thesis has significantly benefited from their insightful comments and discussions.

I received many helpful suggestions from the faculty members and graduate students at the Department of Economics of the Universidad Carlos III de Madrid. In particular, I want to thank Antonia Diaz, Loris Rubini and Ludo Visschers for their comments, suggestions for improvements and ideas for further research.

The thesis has greatly benefited from many useful comments by participants of the seminars and conferences in Madrid, Barcelona, Vigo and Valencia.

I am grateful to Directors of the PhD program Antonio Romero-Medina, Carlos Velasco, Nezih Guner, Klaus Desmet for their support during my stay at the Universidad Carlos III de Madrid and thesis preparation. Also I thank Angelica Aparicio de la Faya and Arancha Alonso for their efforts on organization of my thesis defense.

The research leading to this thesis received the financial support from the Department of Economics of the Universidad Carlos III de Madrid.

Finally, I am most grateful to my family for their support and patience. I could not have done it without their help.

Summary

It is well known that highly volatile and persistent commodity prices significantly affect the global economic activity. Their effect is especially pronounced in small commodity-exporting economies, where primary resources provide an important source of export earnings. In these economies, commodity price changes entail very large effects on the balance of payments, exchange rates, output, sectoral composition and public finance, and, as a result, pose serious problems for the conduct of macroeconomic policy. The goal of this dissertation is to identify and interpret the main stylized facts of business cycles in a protypical small commodity-exporting economy in order to address the problem of stabilization policy in this type of economy.

In the first chapter, I discuss five stylized facts regarding the effects of the world commodity prices on the business cycle properties of a small commodity-exporting economy. These facts can be summarized as follows: i) real commodity prices are positively correlated with external balances (*external balances effect*), ii) real exchange rates are highly volatile and strongly correlated with the real commodity prices, so that an increase (decrease) in commodity prices results in appreciation (depreciation) of the real exchange rate (*commodity currency effect*), iii) windfall income from commodity export is partially spent inside the economy driving up domestic demand (*spending effect*); besides, relative consumption with respect to main trade partners is negatively correlated with the real exchange rate in contrast to predictions of international business cycle models assuming perfect financial markets (*Backus-Smith puzzle*), iv) an increase in commodity export revenues is associated with a decline in the non-commodity tradable sector (*Dutch disease*), and v) there is positive effect of the real commodity price on investment (*investment effect*).

To test for the existence of the previous set of stylized facts, I present a structural dynamic factor model for Canada, which is a nice example of a small commodity-exporting economy. Using a large panel of data on the global economy and Canada it quantifies dynamic responses of a wide variety of variables to two global shocks, explaining most of the volatility in the real commodity prices, namely to negative commodity-specific shock and positive innovation in global demand. The main results may be summarized as follows. First, this chapter confirm the results obtained by Kilian (2009) and Kilian and Murphy (2010) about commodity prices being driven by a variety of global shocks rather

than by any specific one. Secondly, both a positive global demand shock and negative commodity-specific shock result in increasing commodity prices and generate a positive effect on external balances, a commodity currency effect, a Backus-Smith anomaly and a positive investment effect in Canada. However, the Dutch disease and spending effects are only due to the negative commodity-specific shock. By contrast, a positive global demand shock stimulates real output and real expenditures uniformly across industries and sectors of the Canadian economy. Given that a global demand shock contributes significantly to commodity price volatility, this fact may help explain why the Dutch disease effect is so strikingly absent in the data.

In the second chapter, I develop a real business cycle model of a small commodity-exporting economy to analyze the above-mentioned stylized facts. I show that a model with complete markets, separable preferences and no financial frictions is unable to generate these facts. By contrast, once frictions in asset trade are allowed for, the model is capable of reproducing the whole set of stylized facts. The main idea is that these frictions generate a wedge between stochastic discount factors and marginal rates of substitution in consumption which limit international risk sharing and lead to the above-mentioned correlations and volatilities.

In the third chapter, I evaluate the welfare implications of alternative monetary policy regimes in these economies. To do so, I develop a New Keynesian model of a small commodity-exporting economy. In line with the existing literature, welfare analysis shows that fixed nominal exchange rate regimes provide, in general, worse outcomes than flexible exchange rate regimes. My main finding, however, is that the welfare costs of a nominal peg depend crucially on the extent of international risk sharing. In a version of the model with complete and frictionless asset markets, a commodity-exporting economy may insure against world commodity price shocks, so that the real exchange rate volatility becomes small and, as result, welfare losses from the nominal peg become negligible. Conversely, under financial autarky, the fixed nominal exchange rate generates significant volatility of inflation which leads to large welfare costs. This result underscores that it is key for small commodity-exporting economies to implement some kind of cross-country risk-sharing mechanisms. This mechanism would allow to stabilize real exchange rate and reduce welfare costs of nominal peg regime or even promote successful participation in an asymmetric currency union.

Resumen

Es bien conocido que los precios de las materias primas son muy volátiles y persistentes afectando significativamente a la actividad económica mundial. Sin embargo, se conoce bastante menos sobre su impacto en las pequeñas economías exportadoras de dichos inputs intermedios, donde los ingresos derivados de la exportación de los mismos constituyen una importante fuente de recursos económicos. En estas economías, los cambios en los precios de las materias primas exportadas tienen efectos muy apreciables sobre el saldo de la balanza comercial y por cuenta corriente, el tipo de cambio, la demanda interna y la producción, la composición sectorial y las finanzas públicas. En consecuencia, plantean serios problemas para el diseño y manejo de la política macroeconómica. El objetivo de esta tesis es el de identificar e interpretar los principales hechos estilizados de los ciclos económicos en este tipo de economías con el fin de abordar el problema del diseño óptimo de sus políticas de estabilización.

A lo largo de la tesis se analizan cinco hechos estilizados sobre los efectos de los precios mundiales de los productos básicos en las propiedades de los ciclos económicos de las economías con las anteriores características. Estos hechos pueden resumirse de la siguiente manera: i) los precios en términos reales de las materias primas están correlacionados positivamente con los saldos de la balanza de pagos (*efecto de los saldos externos*), ii) el tipo de cambio real es muy volátil y está correlacionado negativamente con los precios reales de dichos productos, de modo que un aumento (disminución) de los precios se traduce en apreciación (depreciación) del tipo de cambio real (*efecto de la moneda mercancía*), iii) los ingresos extraordinarios de la exportación de materias primas se utilizan en buena parte para aumentar la demanda interna (*efecto del gasto*) y, además, el consumo relativo con respecto a los principales socios comerciales se encuentra correlacionado negativamente con el tipo de cambio real, en contraste con las predicciones de los modelos del ciclo económico internacional, bajo el supuesto de mercados financieros perfectos que predicen el signo opuesto en dicha correlación (*paradoja de Backus-Smith*), iv) un aumento en los ingresos por exportaciones de materias primas se asocia con una disminución de la producción en el sector manufacturero (*enfermedad holandesa*), y, finalmente, v) existe un efecto positivo de los precios reales de las materias primas sobre la inversión (*efecto de inversión*).

Para analizar el origen de las perturbaciones que pueden dar lugar al anterior conjunto

de hechos estilizados, en el Capítulo 1 de la tesis se presenta un modelo estructural dinámico de factores comunes (SDFM) estimado con datos de Canadá, una economía que constituye un buen ejemplo de una pequeña economía exportadora de materias primas. El uso de un gran panel de datos tanto sobre la economía canadiense como la global permite cuantificar las respuestas dinámicas de las principales macro-magnitudes a una amplia variedad de perturbaciones de demanda y oferta. Los resultados más importantes son los siguientes. La mayor parte de la volatilidad en los precios de las materias primas exportadas se explica en términos de los dos shocks globales: uno adverso de oferta de materias primas a nivel mundial y otro favorable en la demanda mundial. De esta manera se confirman los resultados obtenidos por Kilian (2009) y Kilian and Murphy (2010) concernientes a que las variaciones en los precios de las materias primas se deben a una variedad de perturbaciones a nivel mundial y no a cualquier otro shock específico del país en cuestión. En segundo lugar, tanto un shock positivo en la demanda global como un shock adverso de oferta de productos básicos da lugar a un aumento de los precios de productos básicos, generando un efecto positivo en los saldos externos, una apreciación del tipo de cambio, una anomalía del tipo Backus-Smith y un efecto positivo de inversión en Canadá. Por el contrario, los efectos de la enfermedad holandesa y del gasto sólo se deben a un shock negativo de oferta de materias primas de carácter específico. Asimismo, un shock positivo de demanda global estimula la producción real y el gasto real de manera uniforme en todos los sectores de la economía canadiense. Teniendo en cuenta que un shock de demanda global contribuye significativamente a la volatilidad de los precios de productos básicos, este hecho podría explicar por qué frecuentemente resulta tan complicado encontrar evidencia de la enfermedad holandesa en los datos analizados.

En el Capítulo 2, se desarrolla un modelo de ciclo económico real de una pequeña economía exportadora de materias primas para analizar la lista de hechos estilizados mencionados anteriormente. Se demuestra que un modelo con mercados completos, preferencias separables y ausencia de fricciones financieras es incapaz de generar estos hechos conjuntamente. Por el contrario, una vez que se permite la existencia de fricciones en el mercado de activos financieros, el modelo es capaz de reproducir todo el conjunto de hechos estilizados. La idea principal es que estas fricciones generan una brecha entre los factores de descuento estocásticos y las tasas marginales de sustitución en el consumo que limitan la distribución internacional del riesgo, dando lugar a las correlaciones y volatilidades mencionadas antes.

En el Capítulo 3, se evalúan las consecuencias en términos de bienestar de regímenes alternativos de la política monetaria en pequeñas economías exportadoras de materias primas. Para ello, se desarrolla u nuevo modelo de corte neo-keynesiano para este tipo de economías. En línea con la literatura existente, el análisis del bienestar muestra que los regímenes de tipo de cambio fijo proporcionan, en general, peores resultados que los regímenes cambiarios flexibles. Sin embargo, la conclusión principal de este capítulo es que los costes del bienestar de un tipo de cambio nominal dependerán fundamentalmente de la extensión de la distribución del riesgo internacional. En una versión del modelo con los mercados de activos completos y sin fricciones, una economía exportadora de productos básicos puede asegurarse contra los shocks de los precios mundiales de dichas materias primas, por lo que la volatilidad del tipo de cambio real se vuelve insignificante, de manera que las pérdidas de bienestar asociadas a un tipo de cambio fijo tienden a ser reducidas. En cambio, si la economía funciona como una autarquía financiera el tipo de cambio nominal fijo genera una gran volatilidad de la inflación que induce unos costes de bienestar muy elevados. Este resultado enfatiza que es clave para las economías exportadoras de productos básicos poner en práctica algún tipo de mecanismo para facilitar distribución internacional de riesgos. Este mecanismo permitiría estabilizar el tipo de cambio real y con ello reducir los costes de bienestar de mantener la paridad nominal fija o incluso promover la participación exitosa en una unión monetaria asimétrica.

Chapter 1

The transmission of international shocks to a small commodity-exporting economy: a dynamic factor model for Canada

1.1 Introduction

It is well acknowledged that the economic and financial integration of the world economy has significantly deepened during the last two decades. As a result, many economic shocks originated in one particular region of the world are quickly transmitted to the rest of the global economy, as it has been once more observed during the course of the recent Great Recession. However, the effects of the global shocks and the mechanisms of their international transmission are hardly uniform across countries.

One of the manifestations of this heterogeneity is the different effect that fluctuations in world commodity prices have on the countries exporting and importing primary resources. On the one hand, an unexpected increase in the world commodity price has a negative effect on commodity-importing economies, worsening their terms of trade and increasing production costs. On the other, this global shock improves terms of trade in commodity-exporting economies, generates large windfall revenues from their commodity exports and stimulates domestic demand and output.

Several stylized facts regarding the effects of fluctuations in commodity prices on the business cycles in commodity-exporting economies are documented in the literature. These facts can be summarized as follows. First, trade and current account balances in these economies are usually positively correlated with the terms of trade and the world prices of exported commodities. When commodity prices are high, the value of their exports is higher than the value of imports, so these countries accumulate foreign assets (or decrease foreign debt), whereas when these prices are low, their trade and current account balances plummet. Moreover, this *external balances effect* is almost fully due to changes in trade balance of primary commodities, as Kilian, Rebucci, and Spatafora (2009) have illustrated for the specific case of the oil-exporting economies.

Secondly, real exchange rates in the resource-rich economies are highly volatile and strongly correlated with the real commodity prices. So, an increase (decrease) in commodity prices results in appreciation (depreciation) of the real exchange rate. This *commodity currency effect* is documented, for example, by Cashin, Cespedes, and Sahay (2004) and Chen and Rogoff (2003).

Thirdly, windfall income from commodity export is partially spent inside the economy driving up domestic demand (*spending effect*). Further, relative consumption between commodity-exporting economy and its trade partners is negatively correlated with its relative price, i.e. the real exchange rate. Notice that this last feature is in contrast with the predictions of many international real business cycle models which suggest, under the assumption of perfect financial markets, that consumption should be higher in the country where its price, converted into a common currency is lower. This collision is known in the literature as the consumption-real exchange rate anomaly or *Backus-Smith puzzle* (Backus and Smith, 1993).

Fourthly, there is an evidence of a positive relationship between commodity prices and investment in commodity-exporting economies (Spatafora and Warner, 1999). Appreciation of the real exchange rate, following the increase in commodity prices, leads to a reduction in the relative price of investment goods, which are predominantly tradable. As a result, investment demand raises, illustrating the so-called *investment effect*.

Finally, rising commodity prices, by appreciating the real exchange rate, lead to a fall in competitiveness and thus to a decrease in the output of the domestic manufacturing sector, whereas output increases in the nontradable and commodity sectors. That is the essence of the so-called *Dutch disease*. Despite the fact that this effect has been widely studied in the literature, there is a striking lack of agreement in the empirical evidence supporting this phenomenon. For example, Spatafora and Warner (1999) fails to detect a contraction in manufacturing sector after an oil price shock for a group of developing oil-exporting countries. By contrast, using gravity trade model and international trade data, Stijns (2003) found that a one percent increase in the world energy price is estimated to decrease real manufacturing exports from an energy-exporting economy by almost half a percent.

It is a fairly common approach in the literature, when studying above-mentioned stylized facts, to assume that the world commodity price changes are exogenous while other global variables in the analysis remain constant. However, this *ceteris paribus* assumption may be misleading, as Kilian (2009) shows in application to oil prices. First, there is a reverse causality from the global macroeconomic variables to commodity prices, so that cause and effect are not generally well defined when relating changes in the real commodity prices to global macroeconomic outcomes. Secondly, commodity prices are driven by different structural shocks, each of which may have direct effects on the global economy as well as indirect effects through the commodity price.

In view of these shortcomings, the goal of this paper is to test for the existence of the previous set of stylized facts in Canada during 1975q1-2010q4 since this country provides a nice example of a small commodity-exporting economy with a fairly rich data set. In particular, to circumvent some of the above-mentioned problems, we follow Kilian (2009) and Kilian and Murphy (2010) in identifying international shocks driving up the world commodity prices from a structural VAR model containing three global variables: global economic activity, global inflation and real commodity price index.[1] Two identification schemes are considered: i) recursive identification and ii) sign identification combined with bounds on some elements of the impact matrix (Kilian and Murphy, 2010). In this fashion, we are able to identify three main global shocks during our sample period: (i) a positive demand shock (GD hereafter), (ii) a negative non-commodity supply shock (GN), and (iii) a negative commodity-specific shock (GC).

Once these three global shocks have been identified, the next step is to analyze their effects on the small commodity-exporting economy (Canada). A natural empirical framework for this exercise is provided by structural dynamic factor models (SDFM) (Stock and Watson, 2005; Forni, Giannone, Lippi, and Reichlin, 2009) and factor-augmented VARs (FAVAR) (Bernanke and Boivin, 2003; Bernanke, Boivin, and Eliasz, 2005; Mumtaz and Surico, 2009; Boivin and Giannoni, 2007) since use of these models implies an efficient and convenient way for analyzing the effect of a small number of structural shocks to a large set of macroeconomic variables (with the number of variables often exceeding the number of observations). As in (Mumtaz and Surico, 2009; Boivin and Giannoni, 2007), we construct a SDFM model containing two blocks: (i) a first block corresponding to the global economy, and (ii) a second block pertaining to the the Canadian economy.

The contribution of this paper is therefore twofold. First, using a SDFM, we are able to quantify the dynamic responses of a wide variety of the aggregate and disaggregate Canadian variables to the above-mentioned three global shocks. Secondly, by means of these dynamic responses, we are able to test for the main stylized facts regarding the effects of fluctuations in the real commodity prices on the business cycle in our small commodity-exporting economy.

The main results of the paper may be summarized as follows. First, our findings confirm the results obtained by Kilian (2009) and Kilian and Murphy (2010) about commodity prices being driven by a variety of global shocks rather than by any specific one.

[1] The set of variables in our model differs slightly from that in Kilian (2009) and Kilian and Murphy (2010). Our model includes global inflation but lacks global commodity supply, given that supply data for many primary commodities are not so readily available as for the oil market.

In particular, all the three global shocks contribute to explain changes in the real commodity prices observed during 1975q1-2010q4, with the GD and GC shocks explaining most of their volatility. Secondly, both a positive global GD shock and negative GC shock result in increasing commodity prices and generate a positive effect on external balances, a commodity currency effect, a Backus-Smith anomaly and a positive investment effect in Canada. However, the Dutch disease and domestic spending effects are only due to the negative GC shock. By contrast, a positive GD shock stimulates real output and real expenditures uniformly across industries and sectors of the Canadian economy without any indication of the Dutch disease or spending effect. Given that a GD shock contributes significantly to commodity price volatility, this fact may help explain why the Dutch disease effect is so strikingly absent in the data.

This rest of the paper is organized as follows. Section 2 presents the main features of the SDFM for a small commodity-exporting economy, discusses identification of the global shocks, data and estimation strategy. Section 3 reports the empirical results. In particular, using dynamic responses of the global and Canadian economies to two (the positive GD and the negative GC shocks, this section illustrates the channels through which the main stylized facts regarding business cycles in a small commodity-exporting economies take place. Section 3 concludes. Three appendices provide more details on the data, estimation and identification methodology.

1.2 Econometric Framework: Structural Dynamic Factor Model

This section presents an empirical framework to identify international shocks driving the world commodity prices and to analyze transmission mechanism of these shocks to a small commodity-exporting economy like Canada.

This framework combines two strands in the empirical literature. The first one is related to the identification and analysis of the main determinants of the commodity prices, mainly as regards to the oil market (Kilian, 2009; Lippi and Nobili, 2009; Kilian and Murphy, 2010). An important finding in this literature is that the world commodity prices are driven by many shocks and the effects of these shocks on global economy can be very different. For example, both a global demand shock and an unanticipated disruption of oil supply generate an increase in oil prices. However, while the first shock stimulates global economic activity, the second one discourages it. In other words, it is incorrect to consider the world commodity prices as exogenous when studying their impact on global economy and formulating appropriate policy responses.

The second strand in the literature is based on the structural dynamic factor models (SDFM) (Stock and Watson, 2005; Forni et al., 2009) and factor-augmented VARs

(FAVAR) (Bernanke and Boivin, 2003; Bernanke et al., 2005; Mumtaz and Surico, 2009; Boivin and Giannoni, 2007). One of the main advantages of these models over the standard VARs is that they provide an efficient and convenient way of analyzing the effect of small number of structural shocks on a large set of macroeconomic variables (with the number of variables often exceeding the number of observations).

1.2.1 The Empirical Model

The model consists of two blocks as in Mumtaz and Surico (2009) and Boivin and Giannoni (2007). The first block corresponds to the global economy as a whole. The second one summarizes information about the Canadian economy. The state of the economy in these two regions is characterized by a small number K of unobserved factors, $(F_t^{*\prime},\ F_t^{\prime})$, where the vector with asterisks denotes global factors, $F_t^* = (F_{Y,t}^*,\ F_{\pi,t}^*,\ F_{C,t}^*)'$. Following Mumtaz and Surico (2009), it is assumed that global factors have an economic interpretation. Specifically, the first factor, $F_{Y,t}^*$, summarizes information about the global economic activity and is extracted from a panel of international series, $X_{Y,t}^*$, characterizing global and regional output, industrial production and trade. The second factor, $F_{\pi,t}^*$ approximates global inflation and is estimated from the international data on consumer and producer prices and GDP deflators, $X_{\pi,t}^*$. Finally, the real world commodity price index, $F_{C,t}^*$, is identified from the panel of price data on various primary commodities, $X_{C,t}^*$.[2] The state of the commodity-exporting economy is measured in turn by a large set of macroeconomic and financial series for Canada, X_t. However, the $K-3$ domestic factors, F_t, have no specific economic interpretation and are extracted from the full panel of Canadian data.

To summarize, the factors and the observable data are related by the following observation equation:

$$\begin{pmatrix} X_{Y,t}^* \\ X_{\pi,t}^* \\ X_{C,t}^* \\ X_t \end{pmatrix} = \begin{pmatrix} \Lambda_Y^* & 0 & 0 & 0 \\ 0 & \Lambda_\pi^* & 0 & 0 \\ 0 & 0 & \Lambda_C^* & 0 \\ \Lambda_Y & \Lambda_\pi & \Lambda_C & \Lambda_H \end{pmatrix} \begin{pmatrix} F_{Y,t}^* \\ F_{\pi,t}^* \\ F_{C,t}^* \\ F_t \end{pmatrix} + \begin{pmatrix} e_{Y,t}^* \\ e_{\pi,t}^* \\ e_{C,t}^* \\ e_t \end{pmatrix} \tag{1.1}$$

where $X_t^* = (X_{Y,t}^{*\prime},\ X_{\pi,t}^{*\prime},\ X_{C,t}^{*\prime})'$ and X_t are data for global and domestic economies, $F_t^* = (F_{Y,t}^*,\ F_{\pi,t}^*,\ F_{C,t}^*)'$ and F_t denote corresponding unobservable factors, Λ_i^* and Λ_j are loading matrices respectively for global and domestic factors, $e_t^* = (e_{Y,t}^{*\prime},\ e_{\pi,t}^{*\prime},\ e_{C,t}^{*\prime})'$ and e_t are zero mean measurement errors, that are uncorrelated with the corresponding common

[2] The real world commodity price index estimated in this paper is more closely correlated with the measured export price index for primary commodities in Canada than the real oil price. It is not surprising, given that Canada is exporting not only energy resources, but also fertilizers, wood and timber, metals, wheat and grains. Using this measured export price index instead of the estimated one does not change the results significantly.

components. Lastly, notice that the global factors are included explicitly into domestic block of the model as illustrated by the last row of (1.1).

The dynamics of the common factors are modeled as a restricted structural VAR:

$$\begin{pmatrix} F_t^* \\ F_t \end{pmatrix} = \begin{pmatrix} \Psi_{11}(L) & 0 \\ \Psi_{21}(L) & \Psi_{22}(L) \end{pmatrix} \begin{pmatrix} F_{t-1}^* \\ F_{t-1} \end{pmatrix} + u_t \tag{1.2}$$

where $\Psi_{ij}(L)$ are lag polynomials of the finite order p, u_t denote reduced form residuals, such that $u_t \sim N(0, \Omega)$ and $u_t = A_0 e_t$, with the structural shocks $e_t \sim N(0, I)$ and $\Omega = A_0 A_0'$. Notice, that we impose the restriction that domestic factors have no any effect on global factors, stressing a small size of the domestic economy.[3] Moreover, it is assumed that global shocks are ordered first and domestic structural shocks have no contemporaneous effect on global factors. In other words, the right upper $3 \times (K-3)$ block of the matrix A_0 is imposed to be zero. The further identifying restrictions on this matrix will be discussed later.

1.2.2 Data

The database is a balanced panel of the quarterly data from 1975q1 to 2010q4. This data set spans 266 series characterizing global and Canadian economies. The foreign block includes data for the world economy (if available) as well as for the large regional blocks (OECD, EU, G7) and the U.S. This block contains three large group of variables: real activity, inflation and real commodity prices. Real activity is measured by real GDP, industrial production, volume of export and import and by index of global real economic activity constructed by Kilian (2009) and based on representative freight rates for various bulk-dry cargoes. Global inflation summarizes data on implicit price deflators of GDP, consumer and producer prices. Real commodity prices consist of a range of commodity price indices for energy, food, agricultural raw materials, base metals and fertilizers collected by the World bank.

The data for Canada contain many different real activity indicators, inflation series, exchange rates, financial variables. In addition to these macro variables, a large number of disaggregated deflator and volume series for consumer expenditure from CANSIM included. Those variables which are nonstationary are first differenced and, in addition, all variables are demeaned and standardized prior to estimation. More details are given in Appendix A.3. Table A.2 summarizes information about the sectoral composition of the Canadian economy whereas Table A.3 illustrates the main business cycle statistics of this economy.

[3] An unrestricted VAR model provides very similar dynamic responses of domestic variables to global shocks. However, it also implies significant but counterintuitive effect of domestic factors on global variables. As a result, estimated global shocks and their historical decompositions differ slightly from those in restricted model.

1.2.3 Estimation

Like in Bernanke et al. (2005), Mumtaz and Surico (2009) and Boivin and Giannoni (2007), the model was estimated using a two-step principal component analysis (PCA). In the first step, the PC were extracted from $X^*_{Y,t}$, $X^*_{\pi,t}$, $X^*_{C,t}$ and X_t to obtain consistent estimates of the common factors. In the second step, these factors were used for estimation of the restricted VAR in (1.2).

Note that, in the first step, we impose the constraint that global factors are included into the principal components for domestic block of the model. So, if these global factors are really common components, they should be captured by the PC of X_t. To remove the global factors from the space covered by the PC of X_t, the approach proposed by Boivin and Giannoni (2007) is used. To do so, the following iterative procedure is adopted in the first step of the estimation. Starting from the initial estimates of $K-3$ principal components F_t from the domestic block of variables X_t, denoted by $F_t^{(0)}$, iteration proceeds through the following steps:

1. Regress X_t on $F_t^{(0)}$ and estimates of the global factors $\hat{F}^*_{Y,t}$, $\hat{F}^*_{\pi,t}$ and $\hat{F}^*_{C,t}$, to obtain $\hat{\Lambda}_Y^{(0)}$, $\hat{\Lambda}_\pi^{(0)}$ and $\hat{\Lambda}_C^{(0)}$

2. Compute $\tilde{X}_t^{(0)} = X_t - \hat{\Lambda}_Y^{(0)}\hat{F}^*_{Y,t} - \hat{\Lambda}_\pi^{(0)}\hat{F}^*_{\pi,t} - \hat{\Lambda}_C^{(0)}\hat{F}^*_{C,t}$

3. Estimate $F_t^{(1)}$ as the first $K-3$ principal components of $\tilde{X}_t^{(0)}$

4. Back to the Step 1.

The benchmark model includes 8 factors for Canada. In any case, the impulse responses do not change significantly if additional domestic factors are considered.[4] This choice implies that the second step in our estimation procedure involves the estimation of a restricted VAR with 11 endogenous variables: 3 global and 8 domestic factors. Two lags are included in the model in order to adequately capture its dynamics. This choice implies a large number of free parameters in the VAR system to be estimated using 144 observations for each variable. Hence, Bayesian methods for estimation of this restricted VAR are used. Details about the estimation procedure are given in Appendix A.1.

1.2.4 Identification of Structural Shocks

This section discusses the identification of the structural shocks. In particular, we are interested in identifying three global shocks: i) an unanticipated expansion of global demand (GD), $\epsilon^*_{D,t}$, ii) a global supply shock, unrelated to commodity markets (GN) , $\epsilon^*_{S,t}$,

[4]Bai and Ng (2002) provide several criteria to determine the number of factors present in the data set, X_t. Their panel information criteria IC_{p1} and IC_{p2}, for example, suggest the presence respectively of 6 and 4 factors in the panel for Canada. However, these criteria do not address directly the question of how many factors should be included in the VAR.

and iii) a global commodity-specific shock (GC), $\epsilon^*_{C,t}$. The last shock is aimed to catch unanticipated changes in the real commodity prices orthogonal to the first two innovations. These changes may be explained by events leading to an unexpected contraction of the global commodity supply as well as by commodity-specific demand shocks, such as an increase in the precautionary demand on commodities as a result of expectations of significant political events.[5]

Further, since the main goal of this study is to analyze the effect of global shocks on a small commodity-exporting economy, we are not particularly interested in identifying the domestic structural shocks. On the contrary, the foreign shocks are identified using two schemes based on recursive ordering and a mixture of sign and impact matrix restrictions. In both schemes the foreign factors are ordered first, implying that the rest of the world does not react instantly to domestic conditions in Canada.

Recursive identification

In the recursive scheme, presented in Table 1.1, the impact matrix corresponding to the foreign 3×3 block is lower triangular. The global economic activity factor $F^*_{Y,t}$ is ordered first, following by the real commodity price index $F^*_{C,t}$ and global inflation $F^*_{\pi,t}$ respectively. This ordering implies that the global supply shock has zero contemporaneous effect on global economic activity and real commodity prices, whereas the commodity-specific shock does not affect immediately the real activity.

Table 1.1: Recursive identification

	Demand Shock, $\epsilon^*_{D,t}$	Commodity Shock, $\epsilon^*_{C,t}$	Supply Shock, $\epsilon^*_{S,t}$
Global Economic Activity, $u^*_{Y,t}$	$\times$	0	0
Real Commodity Price, $u^*_{C,t}$	$\times$	$\times$	0
Global Inflation, $u^*_{\pi,t}$	$\times$	$\times$	$\times$

This recursive identification is not without limitations. First, it imposes zero restrictions on some elements of the impact matrix, in particular, on short-run elasticities of the global economic activity and real commodity price, respectively, to global supply shock. However, there is no specific reason for these exclusion restrictions to hold exactly.

Second, as noted by Kilian (2009) and illustrated once again in this paper, impulse response function of the global economic activity to GC shock is mildly implausible. In

[5]In contrast to Kilian (2009) we did not identify explicitly commodity supply shocks, given that data on production and supply of many primary commodities are not so readily available as for the crude oil market. Moreover, in application to oil market Kilian (2009) and Kilian and Murphy (2010) found that relative contribution of the oil supply shock to fluctuations in real oil price is low. A substantial part of the volatility in the real oil price during 1976-2008 in these papers can be attributed to shocks in global economic activity, with the remainder being largely explained by oil-market specific demand shocks (these speculative demand shocks are ultimately driven by expectations about the availability of future oil supplies).

principle, it is quite plausible that this shock implies large response of the real commodity price on impact. Hence, it is reasonable to expect that this spike in the real price will reduce real activity. Nevertheless, the VAR estimates show that this negative effect becomes apparent only after one year, whereas small, but significantly positive, response of the real activity is observed during the first year following the shock.

Thus, to verify the robustness of the results for the recursive scheme, an identification using sign restrictions on the VAR impulse response function is also used.

Sign restrictions combined with short-run elasticity bounds

In the second scheme, we impose sign restrictions on the impulse responses of global factors to global shocks. In particular, we assume that impulse responses accumulated over 4 quarters should have the signs reported in Table 1.2:

Table 1.2: Sign restrictions on impulse response functions

	Demand Shock, $\epsilon^*_{D,t}$	Commodity Shock, $\epsilon^*_{C,t}$	Supply Shock, $\epsilon^*_{S,t}$
Global Economic Activity, $F^*_{Y,t}$	+	−	−
Real Commodity Price, $F^*_{C,t}$	+	+	−
Global Inflation, $F^*_{\pi,t}$	+	+	+

The sign restrictions are imposed using the rotation procedure proposed by Rubio-Ramirez, Waggoner, and Zha (2010) as described in Appendix A.2. Accordingly, a GD shock is associated with an increase in global activity, inflation, and real commodity prices. A negative GN supply shock implies an increase in inflation, a reduction in real activity and a fall in real commodity prices and, finally, a negative GC shock results in a rise of commodity prices, rising inflation and declining real activity.

A fundamental problem of the VAR model identified using sign restrictions is that, in contrast to exactly-identified VAR, it does not provide a point estimate of the impulse response functions. This model is only set identified. In other words, it does not imply a unique structural model, characterized by the single impact matrix A_0, but a set of models (and a set of matrices $\mathcal{A}_0 = \{A_0 | A_0 A_0' = \Omega\}$) that satisfy the identifying assumptions. This complicates interpretation of the results because medians (or other quantiles) of the impulse responses computed for the different time horizons often correspond to different structural models.

To alleviate this problem, the procedure proposed by Kilian and Murphy (2010) is adopted. These authors narrow down the set of admissible structural models by imposing bounds on some short-run elasticities (i.e., the elements of the impact matrix A_0). In particular, they assume a very small short-run elasticity of oil prices to oil supply as well as a small contemporaneous response of global real activity to oil-market specific demand shocks. Similarly, in this paper we impose the additional restriction on the matrix A_0 that the elasticity of the real global activity to commodity-specific shocks is small and has not to exceed 5% in abolute terms ($|A_0(1,2)| \leq 0,05$). This implies that only those structural models satifying these sign and bound restrictions will be kept for the further analysis.

1.3 Results

This section reports the empirical results of the SDFM presented in the previous section. First, we discuss estimates of the global factors, namely global economic activity, global inflation and real commodity price index, illustrate their dynamic response to global shocks and present historical decompositions of these international factors based on two alternative identification schemes. Second, using data for Canada, we illustrate the main stylized facts regarding the effects of international shocks on business cycles in a small commodity-exporting economy. In particular, we report the dynamic effects of positive global demand (GD) shock and negative global commodity-specific (GC) shock on terms of trade and external balances, exchange rates and relative prices, real GDP and its industrial composition, personal consumption and private investment.

1.3.1 Global common factors and shocks

The global factors were estimated from the international block of the model using procedure discussed in Section 1.2.1. Figure A.1 plots the estimated principal components for real activity, inflation and real commodity prices. These factors match closely an empirical evidence about international business cycles, reported by Kose, Otrok, and Whiteman (2003) and Mumtaz and Surico (2009), as well as developments in the world commodity markets, summarized by Hamilton (2011) and Kilian (2006) (in application to oil markets).

In particular, the global economic activity factor manifests apparently the main global downturns between 1975q1 and 2010q4: double-dip recession at the beginning of 1980s, falls in 1991-1993, the East Asian crisis in 1997-1998, slowdown of the early 2000s after Dot-com bubble collapse and 9/11 attacks, and the Great Recession of the late 2000s. The real commodity price factor in turn reflects the most important events in commodity markets: turbulence of the 1978-1981 ignited by the Iranian revolution and outbreak of the Iran-Iraq war, the oil glut of 1980s, falling commodity prices during the East Asian crisis in 1997-1998, rising commodity demand in 2000s and downturn in commodity markets in 2008-2009. The measure of global inflation encompasses stagflation of the 1970s-early 1980s, rising food and energy prices in 2000s as well as deflation of the late 2000s.

Figure A.2 plots the impulse responses of the international factors to global shocks based on recursive identification (blue line together with 90% credible interval) and the model with sign restrictions (shaded area covering 90% credible set). Two identification schemes provide in general similar results. Positive global demand shock generates a significant expansion in global economic activity, increases global inflation and pushes up real commodity prices, with maximum effect reached within one year.

An unexpected disruption of global supply (or rising inflation expectations) causes a decline in real activity, accelerates inflation and depresses real commodity prices. At the same time, on impact our two identification schemes yield slightly different results for this shock. Under recursive identification negative supply shock has no immediate effect on global activity and real commodity prices. It is a consequence of the zero restrictions imposed in this scheme. In contrast, the model with sign restrictions admits an immediate negative impact (though not significant at 10% level) of the negative supply shock on real activity and commodity prices.

Finally, negative commodity-specific shock causes temporary spike in global inflation and very strong increase in real commodity prices. However, an adverse effect of this shock on real activity is delayed for one year, and for the model with recursive identification this negative effect is not very significant.[6] Moreover, for the recursive scheme this shock has small but significant positive effect on global economic activity during the first two-three quarters. This controversial result is in the line with the findings in Kilian (2009). The model with sign restrictions avoids this implausible behavior by imposing a negative accumulated response of the real activity to commodity-specific shock after four quarters.

Figure A.3 plots historical decompositions of the global economic activity, global inflation and real commodity prices based on two alternative structural models. It illustrates contribution of each of the three global shocks to the dynamics of the international factors during the period from 1975q1 to 2010q4. The results are virtually invariant to the method of identification. First, both models suggest that most of the volatility in global real activity during this period was attributed to global demand shocks. However, positive supply shocks play an increasing role in driving global economic activity starting from the middle of 1990s, what may be explained by rising productivity in emerging economies and trade liberalization. Commodity-specific shocks contributed to economic slowdown in the beginning of 1980s as well as to revival of global economy after the Asian financial crisis in 1997-1998.

Second, this figure shows that all three global shocks played an important role in driving the global inflation. However, in the model with recursive identification an episode of high inflation in the late 70s-early 80s is attributed in a large extent to the negative supply shock, whereas the model with sign restrictions explains it mostly by positive global demand and negative commodity-specific shocks.

And, finally, most of the volatility in the real commodity prices during this period is

[6]This delayed response of the real output to commodity shock conforms well to the results of Rotemberg and Woodford (1996) for United States, which show that one percent increase in oil prices leads to a reduction in output of about 0.25 percent after five-seven quarters (with statistically significant decline only from quarter 3 onwards).

attributed to commodity-specific shocks. This shock catches disruption of oil supply in the late 70s-early 80s, oil glut of the mid of 80s, region-specific downturn in 1997-1998 and speculative spike of commodity prices in the beginning of 2008.[7] However, a substantial part of commodity price dynamics is explained by global demand and supply shocks. In particular, according to this model the Great Recession of the late 2000s was a main reason of falling commodity prices in 2008-2009. On the other hand, positive global supply shocks associated with a strong growth in China and India contributed significantly to the surge in commodity prices in 2000s.

1.3.2 Transmission of international shocks to a small commodity-exporting economy

This section will illustrate, using data for Canada, a dynamic effect of estimated global shocks on business cycles in a small commodity-exporting economy. The most interesting dynamics for this kind of economies is generated by changes in the world commodity prices. Therefore, we concentrate here on two global shocks explaining most of their volatility, namely a negative commodity-specific shock and a positive demand shock. These two shocks induce an increase in commodity prices and, as a result, improve Canada's terms of trade, stimulate its external balances and appreciate its real exchange rate. However, their overall effects on Canadian economy are different, what obscures important regularities specific to commodity-exporting economies, such as Dutch disease or spending effect.

Terms of trade and external balances effects

We will start a discussion of the results by illustrating terms of trade and external balances effects.

First, given that Canada is a net exporter of primary commodities, the rising commodity prices tend to improve its terms of trade, i.e. a ratio of export and import prices. It is in contrast with commodity-importing economies, such as United States or Germany, where commodity prices and terms of trade are negatively correlated. Second, when commodity prices are high the current account and trade balances in commodity-exporting economies tend to rise, whereas at the time of low commodity prices their external balances plummet. In particular, Kilian et al. (2009) illustrate this positive external balances effect in application to oil-exporting economies.

[7] The East Asian financial crisis of 1997-1998 did not generate strong global recession, so our measure of global economic activity fails to account its effect on commodity markets. Moreover, the impact of this crisis was different across commodity groups. Oil prices recovered very quickly, and by the end of 1999 they were on the pre-crisis level. In contrast, prices of food, wood, base metals and fertilizers stagnated until the end of 2003. As a result, our measure of commodity-specific shocks differ slightly from the measure of oil-market specific demand shocks computed by Kilian (2009), especially for the period after 1998.

Figure A.4 plots the impulse responses of the terms of trade and external balances (as % of GDP) to two global shocks: negative commodity-specific shock and positive global demand shock. Both shocks significantly increase real commodity prices and improve terms of trade in Canada. Their effects on external balances are slightly different. An unanticipated negative commodity-specific shock significantly increases trade and current account balances. Moreover, this positive effect is almost fully due to increase in trade balance in primary commodities. In contrast, there is no any evident effect on trade balance in goods excepting primary commodities. Besides, this shock has strong but delayed negative effect on real export and no significant and unambiguous effect on real import, illustrating one of the manifestations of Dutch disease.

Similarly, positive global demand shock increases trade balance in primary commodities with one-year delay and has no any effect on trade balance in non-commodity goods. But its effect on total trade and current account balances (as % of GDP) is not so strong as in the case of negative commodity-specific shock.[8] Besides, this positive shock stimulates global economic activity and international trade, so both real export and real import in Canada significantly increase.

Commodity currency effect and relative prices

Another empirical regularity frequently observed in commodity-exporting economies is a commodity currency effect. More specifically, real exchange rates in these economies are usually very volatile and strongly correlated with prices of the exported commodities. In particular, rising commodity prices result in appreciation of the real exchange rate, whereas their decrease is associated with the real exchange rate depreciation. This effect is well studied in the literature. Cashin et al. (2004), for example, analyzed a long-run cointegrating relationship between the real exchange rates and real prices of exported commodities for the sample of 58 commodity-exporting countries and found that for 19 of these countries this relationship is statistically significant. Similarly, Chen and Rogoff (2003) revealed a long-run co-movement of the real exchange rates and real commodity prices for three developed resource rich economies: Australia, Canada and New Zealand.

Figure A.5 illustrates a commodity currency effect for Canada. Both negative commodity-specific shock and positive global demand shock result in appreciation of the Canada's real effective exchange rate as well as its bilateral real exchange rate with respect to United States.[9] Moreover, this real appreciation in Canada is almost due to appreciation

[8] Positive global demand shock not only improves Canada's terms of trade but also significantly increases its real GDP. As a result both the nominator (external balances in real terms) and denominator (real GDP) rise, and overall effect of this shock on our measure of external balances (in terms of GDP) is not clear.

[9] The real exchange rate is defined here as a price of foreign consumption in terms of consumption in Canada, i.e. $RER_{i,CAN,t} = \frac{NER_{i,CAN,t}P_{i,t}}{P_{CAN,t}}$, where $NER_{i,CAN,t}$ is a nominal exchange rate in terms of Canadian dollar per unit of country i currency, $P_{i,t}$ and $P_{CAN,t}$ are, respectively, foreign and Canadian consumer price indices. So, an appreciation of the real (nominal) exchange rate in Canada means a

of the nominal exchange rate. At the same time, the ratio of U.S. and Canadian consumer price indices, $\frac{P_{USA,t}}{P_{CAN,t}}$, barely changes after global commodity-specific shocks and slightly increases in response to global demand shock, reflecting a foreign inflation induced by rising global demand.

Following Betts and Kehoe (2006, 2008), we decompose the bilateral real exchange rate $RER_{US,CAN,t}$ into two components:

$$RER_{US,CAN,t} = \left(\frac{NER_{US,CAN,t}P^T_{US,t}}{P^T_{CAN,t}}\right)\left(\frac{P^T_{CAN,t}}{P_{CAN,t}}/\frac{P^T_{US,t}}{P_{US,t}}\right) \quad (1.3)$$

The first component denotes the real exchange rate of traded goods, $RER^T_{US,CAN,t}$. It measures deviations from the law of one price for traded goods in Canada and United States.[10] To approximate prices of traded goods we used producer price index in manufacturing for these two countries. The second factor, denoted as $RER^N_{US,CAN,t}$, captures cross-country differences in internal relative prices. So, if the prices of traded goods satisfy the law of one price exactly, $NER_{US,CAN,t}P^T_{US,t} = P^T_{CAN,t}$, and a composition of consumer basket is the same across countries, all the dynamics of the real exchange rate will be attributed to relative changes in prices of non-traded goods, $\frac{NER_{US,CAN,t}P^N_{US,t}}{P^N_{CAN,t}}$.

Figure A.5 plots the dynamic effect of global shocks to these two factors. Both shocks significantly appreciate real exchange rate for traded goods, $RER^T_{US,CAN,t}$, invalidating the law of one price. It may be explained by the deficiency of my measure of price index for traded goods (some goods covered by the PPI are actually non-traded), by cross-country differences in composition of the baskets for this index, as well as by the fact that manufacturing prices in two countries are sticky and set in different currencies (at least for domestic markets).[11] This last fact implies that the nominal exchange rate changes have a strong short-run effect on the real exchange rate for traded goods.

This plot illustrates also a significant but not so strong appreciating effect of the global commodity-specific shock on the second (relative price) component of the real exchange rate in Canada, $RER^N_{US,CAN,t}$. That is in line with the results in Betts and Kehoe (2006) which observed positive correlation between bilateral U.S./Canada real exchange rate and its relative price factor. In contrast, global demand shock yields only very week internal appreciation on impact, whereas after one year this measure of the real exchange rate tends to depreciate following rising global inflation.

Figure A.5 reports also the effect of global shocks on disaggregated prices, namely on the implicit price deflators for disaggregated groups of personal consumption in Canada (as in Boivin, Giannoni, and Mihov, 2009). There is strong evidence of heterogeneity

decrease in $RER_{i,CAN,t}$ ($NER_{i,CAN,t}$).

[10]Notice that this ratio is also affected by any differences in the compositions of the baskets of traded goods across countries.

[11]Notice, however, that 96% of Canadian export to United States are priced in U.S. dollars (Gopinath and Rigobon, 2008).

in responses. Both shocks generate strong immediate positive effect on energy prices, whereas the rest of prices manifest diverse dynamics. In the long run, however, there is rising trend in prices of non-energy goods, reflecting increased costs of their production in an environment of high commodity prices.

Spending effect and Backus-Smith puzzle

Soaring commodity prices significantly improve terms of trade in Canada and generate windfall revenues from its commodity export, as shown in Section 1.3.2. Their overall effect on economy depends crucially on the way this windfall income is spent. A positive response of external balances in Canada to negative commodity-specific shock (and to a lesser extent to positive global demand shock) signals that at least a part of commodity revenues is saved abroad, leveling their effect on domestic economy. However, the rest of this income is spent inside the country affecting its output and final expenditures.

Figure A.6 illustrates this spending effect for Canadian economy. Negative commodity-specific shock has no any significant effect on real GDP in Canada. Total employment and total industrial capacity utilization are barely affected too. That is in contrast to its strong[12] but delayed negative effect on global economic activity. Moreover, this shock has positive and significant impact on final domestic expenditures in Canada. Most of this growth is explained by increasing current expenditures of government, enjoying a surge in tax revenues from commodity sector, and real private investments. Real personal consumption expenditures also manifest a small positive response on impact, but this effect disappears very quickly.

In contrast to negative commodity-specific shock, positive global demand shock stimulates global economic activity and international trade. As a result, this shock has significant and unambiguous positive effect on real GDP and real final domestic expenditures in Canada, as well as on its total employment and industrial capacity utilization. This strong growth is triggered mostly by higher foreign demand and obscures an immediate effect of windfall income from commodity export. Besides, real current government expenditures do not change whereas real government investment gradually decreases, signaling about countercyclical character of fiscal policy.

Now we will look more closely at the effects of global shocks on personal consumption in Canada. Figure A.7 illustrates impulse responses of the real expenditures on large aggregated groups of goods, namely on durable and semi-durable goods, and services, as well as on disaggregated series. Implications of the negative commodity-specific shock for aggregated groups are very similar to that for total real consumption. However, dynamic responses of disaggregated goods (except of energy and food) are mostly positive, whereas disaggregated services illustrate no uniform dynamics, indicating that there is a

[12] at least for the model with sign restrictions

small (but insignificant) substitution effect.[13] In contrast, a positive global demand shock has an uniform and strong positive effect on all aggregated and disaggregated groups of consumption.[14]

Another interesting fact is associated with relative consumption, i.e. ratio of real personal consumption expenditures, between Canada and United States. An empirical evidence suggests that relative consumption across countries, does not move in any systematic way with its relative price, i.e. real exchange rate. That is in contrast to predictions of many international business cycle models assuming perfect financial markets, which suggest that consumption should be higher in the country where its price, converted into a common currency is lower. This collision is known in an economic literature as consumption-real exchange rate anomaly or Backus-Smith puzzle (Backus and Smith, 1993). Although this puzzle is observed not only for commodity-exporting economies, for the last group it is especially pronounced. Negative, not predicted positive, correlation of the relative consumption and real exchange rate is often reported for these countries. Along with volatile and negatively correlated with commodity price real exchange rate it may be considered as a signal of imperfections in international risk sharing.

Figure A.7 plots dynamic responses of the relative consumption between Canada and United States to global shocks. As shown earlier, negative commodity-specific shock has only a small and short-living positive effect on real personal consumption in Canada. However, it implies a strong and permanent positive response of relative consumption between Canada and United States. Given that real exchange rate appreciates after this shock, this shock generates strong negative correlation between relative consumption and its relative price, illustrating Backus-Smith puzzle and indicating about imperfections in risk sharing between these two countries. In contrast, positive global demand shock results in a strong growth of personal consumption in Canada but has no any significant effect on its relative consumption with United States. This last fact, however, does not say that global demand shocks are perfectly insured. A full risk sharing would imply instead a decrease in personal consumption relative to United States, following its rising relative price (appreciating real exchange rate).

[13]Recall, that negative commodity-specific shock results in an appreciation of the relative price component of the real exchange rate. Besides, there is some evidence (not reported in this paper) that after this shock the prices of durable consumer goods decrease relative to prices of services.

[14]Figure A.7 reports two counterintuitive negative responses of disaggregated series for services after positive global demand shock. However, it is simply an incidental result of demeaning and normalization procedure, essential for an extraction of principal components. These two series correspond to 'gross imputed rent' and 'gross paid rent' (in constant prices), which barely manifest any volatility except of long-run rising trend. Without normalization (by standard deviations) these responses were hardly distinguishable from zero.

Investment effect

Section 1.3.2 illustrates that a substantial portion of the windfall revenues from commodity export in Canada is channeled into the real private investments in fixed capital. However, in addition to this direct spending effect, there is another indirect propagation mechanism of global shocks to private investment growth. More specifically, an appreciation of the real exchange rate, associated with an increase in commodity prices, results in decreasing relative prices of investment goods, which are predominantly tradable. As a result, investment demand increases. Much of this investment goes into the nontradable and commodity-producing sectors of the economy (see Spatafora and Warner, 1999).

Figure A.8 plots impulse responses of the business gross fixed capital formation, as well as its components and prices, to global shocks. As shown earlier, negative commodity-specific shock generates a positive response of the total real investment in Canada. Besides, its price deflator initially decreases following appreciation of the nominal exchange rate. That is in contrast to consumer price index, which increases after a spike in commodity prices. Moreover, most of this deflation is explained by its tradable component, namely 'machinery and equipment', whereas price deflators of the investments in residential and non-residential structures (produced by non-tradable construction) tend to increase. However, a main growth engine of the private investment after this global shock is an investment in non-residential structures. Investment in machinery and equipment increases too, but its growth is not so strong. Besides, residential investments are barely affected by this shock.

Positive global demand shock has similar implications for the price deflators of private investment in fixed capital. Price index of total investment slightly decreases on impact with most of this decrease explained by investment in machinery and equipment. However, in contrast to negative commodity-specific shock, this positive shock results in a strong growth of all investment components, including residential investments.

Dutch disease

Dutch disease is perhaps the most famous phenomenon associated with commodity-exporting economies. This economic concept explains a relationship between an increase in export revenues from primary commodities and a decline in the non-commodity tradable sector, mainly manufacturing. The underlying mechanism is the following. An increase in export of primary commodities will appreciate real exchange rate, making non-commodity exports more expensive. As a result, the manufacturing sector becomes less competitive and its output declines, whereas output of nontradable and commodity sectors increases. Simultaneously, labor and capital move from manufacturing to booming sectors of the economy (see Corden, 1984, for more details).

Dutch disease effect is well-studied in economic literature (see Stijns, 2003, for good review). However, there is striking absence of unambiguous evidence for this phenomenon from data. For example, Spatafora and Warner (1999) fails to detect a contraction in manufacturing sector after oil price shock for a group of developing oil-exporting countries. In contrast, using gravity trade model and international trade data, Stijns (2003) reports that a one percent increase in world energy price is estimated to decrease real manufacturing exports from energy-exporting economy by almost half a percent. The main reason of these disagreements is that it is very difficult to disentangle relative price effects of commodity price fluctuations from their impact on the domestic and international macroeconomic conditions. Besides, these commodity price changes themselves may be results of changing global demand or supply.

An empirical model presented in this paper illustrates these difficulties. Figure A.9 plots impulse responses of the real GDP in the main sectors of Canadian economy, namely in mining, manufacturing, services, utilities and construction, as well as for disaggregated industries in manufacturing and services, to negative commodity-specific shock and positive global demand shock. Strikingly, these two shocks imply completely different structural dynamics in a small commodity-exporting economy.

As in Section 1.3.2, negative commodity-specific shock has no any evident effect on the aggregate output. However, real GDP responses for the main sectors are very diverse, illustrating Dutch disease symptoms. First, this shock has significant positive effect on commodity-producing tradable sector, mining, with a maximum increase after 3 quarters. Nontradable sectors reap the benefits too. Real GDP in services has statistically significant increase on impact, construction and utilities are booming. In contrast, non-commodity tradable sector, manufacturing, unambiguously declines following vanishing foreign demand, with a maximum decrease in output after one year.[15] Second, impulse responses of disaggregated series for manufacturing and services illustrate the same pattern. Manufacturing industries tend to decrease with the lapse of time, whereas service-producing industries are slightly rising initially but their dynamics become disperse afterwards.

Positive global demand shock also increases the real commodity prices and appreciates the real exchange rate. But, in contrast to negative commodity-specific shock, its effect on real GDP in industries is uniform: positive increase in output with the maximum effect after 3-4 quarters. Taking into account that these two shocks explains a sizable part of the volatility in commodity prices and domestic and global economic activity, it is not surprise that Dutch disease is so often undetectable in data.

Figure A.10 supplements this story with dynamic responses of capacity utilization and employment. Negative commodity-specific shock has no any significant effect on total industrial capacity utilization. However, this shock implies more intensive capacity utilization in mining, more excess capacity in manufacturing and no any significant re-

[15] Recall from Section 1.3.2 that real export is declining too.

sponse in construction. In contrast, number of employed in industries hardly changes, except of construction, where employment slightly increases after 2-3 quarters. Positive global demand shock in turn has strong and uniform positive effect on capacity utilization and employment across industries.

Monetary policy and financial variables

To finish the discussion, we report here dynamic responses of the selected monetary and financial indicators in Canada. Both negative commodity-specific shock and positive global demand shock imply strong growth in the S&P/TSX Composite Index. It is not very surprising taking into account that more mining and oil&gas companies are listed on Toronto Stock Exchange than on any other exchange in the world.

Another interesting question is how monetary authority in Canada responds to global shocks. Several observations are worth mentioning. First, total foreign exchange reserves are hardly changes after these two shocks indicating that Canadian dollar floats freely and the Bank of Canada does not intervene systematically in foreign exchange markets in response to changing international macroeconomic conditions. Second, there is a weak indication that Bank of Canada responds to negative commodity-specific shock by lowering interest rates. However, the model with sign restrictions says that this effect is insignificant. In contrast, Bank of Canada unambiguously rises its interest rates in response to positive global demand shocks, fighting excessive foreign demand and inflation.

And, finally, both shocks result in an endogenous expansion of banking credit and broad money, though for the negative commodity-specific shock this effect is not very strong.

1.4 Conclusions

This paper studied the effect of international shocks on a small commodity-exporting economy. Using structural factor model we quantified the dynamic effects of a wide variety of Canadian variables to two global shocks, explaining the most of the volatility in real commodity prices, namely to negative commodity-specific shock and to positive innovation in global demand. Then we illustrated the main stylized facts regarding the effects of fluctuations in the real commodity prices on business cycles in a small commodity-exporting economy.

This paper supports the viewpoint that commodity prices are driven by several global shocks. In particular, global demand shock, commodity-specific shock and global non-commodity supply shock contributed significantly to changes in the real commodity prices during observed period, with the first two shocks explaining most of their volatility. Moreover, both positive global demand shock and negative commodity-specific shocks result in increasing commodity prices and generate positive effect on external balances, commodity currency effect, Backus-Smith anomaly and positive investment effect in Canada. However, Dutch disease and spending effect are clearly illustrated only by the negative commodity-specific shock. In contrast, positive innovation in global demand stimulates real output and real expenditures uniformly across industries and sectors of the Canadian economy without any indication of the Dutch disease or spending effect. Given that global demand shock contributes significantly to commodity price volatility, this fact can explain why Dutch disease effect is so strikingly absent in the data.

Appendix A

Appendices to Chapter 1

A.1 Estimation method

The restricted VAR has a different set of explanatory variables in each equation and may be estimated as a system of seemingly unrelated regressions (SUR). In particular, we can write this system as

$$y_t = X_t\beta + \epsilon_t \tag{A.1}$$

where $y_t = \begin{pmatrix} y_{1t} & y_{2t} & \dots & y_{Kt} \end{pmatrix}'$, $\beta = \begin{pmatrix} \beta_1' & \beta_2' & \dots & \beta_K' \end{pmatrix}'$, X_t is a block-diagonal matrix with blocks x_{kt}' containing the t-th observation of the vector of explanatory variables relevant for the k-th variable and $\epsilon_t = \begin{pmatrix} \epsilon_{1t} & \epsilon_{2t} & \dots & \epsilon_{Kt} \end{pmatrix}'$ with $\epsilon_t \sim N(0, \Sigma)$.

A Bayesian estimator of the restricted VAR was employed in this paper (see Koop, Poirier, and Tobias, 2007). A commonly used prior for this model is an independent normal-Wishart prior:

$$p(\beta, \Sigma^{-1}) \propto \phi(\beta|\underline{\beta}, \underline{V}) f_W(\Sigma^{-1}|\underline{H}, \underline{v})$$

with $\phi(\cdot)$ and $f_W(\cdot)$ denoting respectively Normal and Wishart probability density functions.

The conditional posterior distribution of the VAR coefficients is given then by:

$$\beta|y, \Sigma^{-1} \sim N(\overline{\beta}, \overline{V}) \tag{A.2}$$

where $\overline{V} = \left(\underline{V}^{-1} + \sum_{t=1}^{T} X_t'\Sigma^{-1}X_t\right)^{-1}$ and $\overline{\beta} = \overline{V}\left(\underline{V}^{-1}\underline{\beta} + \sum_{t=1}^{T} X_t'\Sigma^{-1}y_t\right)$.

The posterior for Σ^{-1} conditional on β is computed as:

$$\Sigma^{-1}|y, \beta \sim W(\overline{H}, \overline{v}) \tag{A.3}$$

where $\overline{H} = \left(\underline{H}^{-1} + \sum_{t=1}^{T}(y_t - X_t\beta)(y_t - X_t\beta)'\right)^{-1}$ and $\overline{v} = T + \underline{v}$.

In this paper we assume an uninformative prior: $\underline{V}^{-1} = 0$, $\underline{v} = 0$ and $\underline{H}^{-1} = 0$. To approximate the posterior distribution in the model we use a Gibbs sampler that sequentially draws from the normal $\phi(\beta|y, \Sigma^{-1})$ and the Wishart $f_W(\Sigma^{-1}|y, \beta)$.

A.2 Identification using sign and bound restrictions

The sign restrictions are imposed using procedure based on Rubio-Ramirez et al. (2010). Let B_0 be a structural impact matrix computed using the Cholesky decomposition of the reduced form variance-covariance matrix Ω with the global factors ordered first, i.e. $\Omega = B_0 B_0'$. Let $\tilde{Q}$ be identity matrix with the foreign (upper-left) block substituted by any (rotational) orthogonal 3×3 matrix, such that $\tilde{Q}\tilde{Q}' = I$. Then, multiplying the impact matrix B_0 by $\tilde{Q}$ yields a new structural impact matrix $\tilde{B}_0 = B_0\tilde{Q}$ (with the global factors ordered first again). Notice, that $\tilde{B}_0\tilde{B}_0' = \Omega$. Drawing repeatedly from the set of orthogonal rotational matrices one can generate a wide range of possible choices for the structural model.

The algorithm consists of the following steps:

1. Compute the Cholesky decomposition B_0^k of the posterior draw k of the reduced form variance-covariance matrix Ω^k with the global factors ordered first.

2. Draw an independent standard normal 3×3 matrix X and let $X = QR$ be the QR decomposition of X with the diagonal of R normalized to be positive. Then Q is a rotational orthogonal matrix and has the uniform (or Haar) distribution. Substitute the upper-left diagonal block of the identity matrix $\tilde{Q}$ by Q.

3. Compute $A_0^k = B_0^k\tilde{Q}$. If this model satisfies the sign and bound restrictions, keep it. Otherwise, move to the next Gibbs iteration.

A.3 Description of data

Data span the period from the first quarter of 1975 to the forth quarter of 2010. The format contains: i) series code, ii) description, iii) source of data, iv) transformation code and v) variance explained by its common components. The transformation codes are: 1 – no transformation; 2 – first difference; 4 – logarithm; 5 – first difference of logarithm. The data set contains 266 quarterly series with no missing observations. The main sources of data are OECD EO, World bank GEM, CANSIM and FRED2 databases.

Global Economic Activity Series

	Series ID	Title	Source	Code	R^2
1	GDP-OECD	Real gross domestic product, OECD, SA	OECD	5	0,88
2	GDP-G7	Real gross domestic product, G7, SA	OECD	5	0,80
3	GDP-EU15	Real gross domestic product, EU15, SA	OECD	5	0,67
4	GDP-US	Real gross domestic product, USA, SA	OECD	5	0,50
5	IND-G7	Industrial production index, G7, SA	OECD	5	0,91
6	IND-EU	Industrial production index, OECD Europa, SA	OECD	5	0,78
7	IND-US	Industrial production index, USA, SA	OECD	5	0,69
8	EXP-WORLD	Export (volume), World, SA	OECD	5	0,81
9	EXP-OECD	Export (volume), OECD, SA	OECD	5	0,84
10	IMP-WORLD	Import (volume), World, SA	OECD	5	0,82
11	IMP-OECD	Import (volume), OECD, SA	OECD	5	0,85
12	DCBFR	Index of Dry Cargo Bulk Freight Rates	Kilian (2009)	2	0,09

Global Inflation Series

	Series ID	Title	Source	Code	R^2
1	DGDP-OECD	Deflator of gross domestic product, OECD, SA	OECD	5	0,88
2	DGDP-G7	Deflator of gross domestic product, G7, SA	OECD	5	0,88
3	DGDP-EU	Deflator of gross domestic product, OECD Europa, SA	OECD	5	0,83
4	DGDP-EU15	Deflator of gross domestic product, EU15, SA	OECD	5	0,84
5	DGDP-US	Deflator of gross domestic product, USA, SA	OECD	5	0,88
6	CPI-OECD	Consumer price index, all items, OECD, SA	OECD	5	0,82
7	CPI-G7	Consumer price index, all items, G7, SA	OECD	5	0,92
8	CPI-EU	Consumer price index, all items, OECD Europa, SA	OECD	5	0,70
9	CPI-US	Consumer price index, all items, USA, SA	OECD	5	0,80
10	CPINEF-OECD	Consumer price index, all items, non-food, non-energy, OECD, SA	OECD	5	0,68
11	CPINEF-G7	Consumer price index, all items, non-food, non-energy, G7, SA	OECD	5	0,85
12	CPINEF-EU	Consumer price index, all items, non-food, non-energy, OECD Europa, SA	OECD	5	0,64
13	CPINEF-US	Consumer price index, all items, non-food, non-energy, USA, SA	OECD	5	0,82
14	PPIM-US	Total producer prices, manufacturing, USA, SA	OECD	5	0,43
15	PPIFG-US	Total producer prices, finished goods, USA, SA	OECD	5	0,49

Real Commodity Prices Series

	Series ID	Title	Source	Code	R^2
1	RCP-ENERGY	Commodity price index, constant 2000 US$, Energy, SA	WB - GEM	5	0,54
2	RCP-FOOD	Commodity price index, constant 2000 US$, Agr., Food, SA	WB - GEM	5	0,48
3	RCP-RAW	Commodity price index, constant 2000 US$, Agr., Raw Materials, SA	WB - GEM	5	0,59
4	RCP-METALS	Commodity price index, constant 2000 US$, Base Metals, SA	WB - GEM	5	0,61
5	RCP-FERT	Commodity price index, constant 2000 US$, Fertilizers, SA	WB - GEM	5	0,25

Canadian Economy Series
Gross domestic product, expenditure-based, constant 2002 prices

	Series ID	Title	Source	Code	R^2
1	GDP-CAN	Gross domestic product at market prices, SA	CANSIM	5	0,75
2	PC-CAN	Personal expenditure on consumer goods and services, SA	CANSIM	5	0,88
3	PCG-CAN	Personal expenditure on consumer goods, SA	CANSIM	5	0,75
4	PCDUR-CAN	Personal expenditure on durable goods, SA	CANSIM	5	0,63
5	PCSDUR-CAN	Personal expenditure on semi-durable goods, SA	CANSIM	5	0,78
6	PCNDUR-CAN	Personal expenditure on non-durable goods, SA	CANSIM	5	0,42
7	PCSER-CAN	Personal expenditure on services, SA	CANSIM	5	0,54
8	GC-CAN	Government current expenditure on goods and services, SA	CANSIM	5	0,09
9	GGFC-CAN	Government gross fixed capital formation, SA	CANSIM	5	0,23
10	GINV-CAN	Government investment in inventories, SA	CANSIM	1	0,29
11	BGFC-CAN	Business gross fixed capital formation, SA	CANSIM	5	0,76
12	RES-CAN	Residential structures, SA	CANSIM	5	0,56
13	NRESEQ-CAN	Non-residential structures and equipment, SA	CANSIM	5	0,69
14	NRES-CAN	Non-residential structures, SA	CANSIM	5	0,51
15	EQ-CAN	Machinery and equipment, SA	CANSIM	5	0,57
16	BINV-CAN	Business investment in inventories, SA	CANSIM	1	0,60
17	BNFINV-CAN	Business investment in non-farm inventories, SA	CANSIM	1	0,60
18	BFINV-CAN	Business investment in farm inventories, SA	CANSIM	1	0,06
19	EXP-CAN	Exports of goods and services, SA	CANSIM	5	0,69

20	EXPG-CAN	Exports of goods, SA	CANSIM	5	0,66
21	EXPS-CAN	Exports of services, SA	CANSIM	5	0,24
22	IMP-CAN	Imports of goods and services, SA	CANSIM	5	0,69
23	IMPG-CAN	Imports of goods, SA	CANSIM	5	0,65
24	IMPS-CAN	Imports of services, SA	CANSIM	5	0,45
25	FDD-CAN	Final domestic demand, SA	CANSIM	5	0,85

Gross domestic product, expenditure-based, implicit price deflator

	Series ID	Title	Source	Code	R^2
26	PGDP-CAN	Gross domestic product, SA	CANSIM	5	0,81
27	PPC-CAN	Personal expenditure on consumer goods and services, SA	CANSIM	5	0,93
28	PPCG-CAN	Personal expenditure on consumer goods, SA	CANSIM	5	0,86
29	PPCDUR-CAN	Personal expenditure on durable goods, SA	CANSIM	5	0,65
30	PPCSDUR-CAN	Personal expenditure on semi-durable goods, SA	CANSIM	5	0,79
31	PPCNDUR-CAN	Personal expenditure on non-durable goods, SA	CANSIM	5	0,77
32	PPCSER-CAN	Personal expenditure on services, SA	CANSIM	5	0,86
33	PGC-CAN	Government current expenditure on goods and services, SA	CANSIM	5	0,56
34	PGGFC-CAN	Government gross fixed capital formation, SA	CANSIM	5	0,61
35	PBGFC-CAN	Business gross fixed capital formation, SA	CANSIM	5	0,64
36	PRES-CAN	Residential structures, SA	CANSIM	5	0,37
37	PNRESEQ-CAN	Non-residential structures and equipment, SA	CANSIM	5	0,75
38	PNRES-CAN	Non-residential structures, SA	CANSIM	5	0,54
39	PEQ-CAN	Machinery and equipment, SA	CANSIM	5	0,77
40	PEXP-CAN	Exports of goods and services, SA	CANSIM	5	0,69
41	PEXPG-CAN	Exports of goods, SA	CANSIM	5	0,68
42	PEXPS-CAN	Exports of services, SA	CANSIM	5	0,70
43	PIMP-CAN	Imports of goods and services, SA	CANSIM	5	0,89
44	PIMPG-CAN	Imports of goods, SA	CANSIM	5	0,86
45	PIMPS-CAN	Imports of services, SA	CANSIM	5	0,86
46	PFDD-CAN	Final domestic demand, SA	CANSIM	5	0,94

Exchange rates and external balances

	Series ID	Title	Source	Code	R^2
47	NEER-CAN	Nominal Effective Exchange Rate	BIS	5	0,79
48	NERUS-CAN	Bilateral Nominal Exchange Rate, CAD/USD	CANSIM	5	0,87
49	REER-CAN	Real Effective Exchange Rate	BIS	5	0,79
50	RERUS-CAN	Bilateral Real Exchange Rate, Canada vs. USA	CANSIM	5	0,88
51	RERT-CAN	Real Exchange Rate, traded goods (PPI)	CANSIM	5	0,78
52	RERN-CAN	Real Exchange Rate, internal relative prices (PPI/CPI)	CANSIM	5	0,56
53	CA-CAN	Current account balance, % of GDP, SA	CANSIM	1	0,72
54	TB-CAN	Trade balance (goods and services), % of GDP, SA	CANSIM	1	0,70
55	TBG-CAN	Trade balance (goods, all types), % of GDP, SA	CANSIM	1	0,69
56	TBC-CAN	Trade balance (goods, primary commodities), % of GDP, SA	CANSIM	1	0,66
57	TBNC-CAN	Trade balance (goods, except of primary commodities), % of GDP, SA	CANSIM	1	0,63

Personal expenditures, constant 2000 prices

	Series ID	Title	Source	Code	R^2
58	PCDIF-CAN-US	Personal consumption differential in Canada and USA, logs, SA	CANSIM, FRED2	2	0,53
59	PCFNAB-CAN	Food and non-alcoholic beverages, SA	CANSIM	5	0,19
60	PCAB-CAN	Alcoholic beverages bought in stores, SA	CANSIM	5	0,21
61	PCTOB-CAN	Tobacco products, SA	CANSIM	5	0,16
62	PCMBC-CAN	Men's and boys' clothing, SA	CANSIM	5	0,55
63	PCWGC-CAN	Women's, girl's and children's clothing, SA	CANSIM	5	0,51
64	PCFW-CAN	Footwear, SA	CANSIM	5	0,44
65	PCGIR-CAN	Gross imputed rent, SA	CANSIM	5	0,39
66	PCGPR-CAN	Gross paid rent, SA	CANSIM	5	0,29
67	PCOS-CAN	Other shelter expenses, SA	CANSIM	5	0,29
68	PCEL-CAN	Electricity, SA	CANSIM	5	0,17
69	PCNG-CAN	Natural gas, SA	CANSIM	5	0,36
70	PCOF-CAN	Other fuels, SA	CANSIM	5	0,31
71	PCFC-CAN	Furniture, carpets and other floor coverings, SA	CANSIM	5	0,57
72	PCHA-CAN	Household appliances, SA	CANSIM	5	0,67
73	PCSDF-CAN	Semi-durable household furnishings, SA	CANSIM	5	0,64
74	PCNHS-CAN	Non-durable household supplies, SA	CANSIM	5	0,32
75	PCDCC-CAN	Domestic and child care services, SA	CANSIM	5	0,15
76	PCOHS-CAN	Other household services, SA	CANSIM	5	0,18
77	PCMC-CAN	Medical care, SA	CANSIM	5	0,18
78	PCHC-CAN	Hospital care and the like, SA	CANSIM	5	0,44
79	PCOMC-CAN	Other medical care expenses, SA	CANSIM	5	0,15
80	PCDPH-CAN	Drugs and pharmaceutical products, SA	CANSIM	5	0,16
81	PCNUMV-CAN	New and used (net) motor vehicles, SA	CANSIM	5	0,44
82	PCMVRP-CAN	Motor vehicle repairs and parts, SA	CANSIM	5	0,19
83	PCMFL-CAN	Motor fuels and lubricants, SA	CANSIM	5	0,29
84	PCOAR-CAN	Other auto related services, SA	CANSIM	5	0,21
85	PCPT-CAN	Purchased transportation, SA	CANSIM	5	0,26
86	PCCOM-CAN	Communications, SA	CANSIM	5	0,27
87	PCRSC-CAN	Recreational, sporting and camping equipment, SA	CANSIM	5	0,66

88	PCRES-CAN	Reading and entertainment supplies, SA	CANSIM	5	0,47
89	PCRS-CAN	Recreational services, SA	CANSIM	5	0,26
90	PCECS-CAN	Education and cultural services, SA	CANSIM	5	0,05
91	PCPE-CAN	Personal effects not elsewhere classified, SA	CANSIM	5	0,31
92	PCPC-CAN	Personal care, SA	CANSIM	5	0,27
93	PCRAS-CAN	Restaurants and accommodation services, SA	CANSIM	5	0,46
94	PCFLS-CAN	Financial and legal services, SA	CANSIM	5	0,12
95	PCNPO-CAN	Operating expenses of non-profit organizations, SA	CANSIM	5	0,11

Personal expenditures, implicit price deflator

	Series ID	Title	Source	Code	R^2
96	PPCFNAB-CAN	Food and non-alcoholic beverages, SA	CANSIM	5	0,45
97	PPCAB-CAN	Alcoholic beverages bought in stores, SA	CANSIM	5	0,55
98	PPCTOB-CAN	Tobacco products, SA	CANSIM	5	0,28
99	PPCMBC-CAN	Men's and boys' clothing, SA	CANSIM	5	0,60
100	PPCWGC-CAN	Women's, girl's and children's clothing, SA	CANSIM	5	0,55
101	PPCFW-CAN	Footwear, SA	CANSIM	5	0,58
102	PPCGIR-CAN	Gross imputed rent, SA	CANSIM	5	0,78
103	PPCGPR-CAN	Gross paid rent, SA	CANSIM	5	0,81
104	PPCOS-CAN	Other shelter expenses, SA	CANSIM	5	0,15
105	PPCEL-CAN	Electricity, SA	CANSIM	5	0,38
106	PPCNG-CAN	Natural gas, SA	CANSIM	5	0,23
107	PPCOF-CAN	Other fuels, SA	CANSIM	5	0,56
108	PPCFC-CAN	Furniture, carpets and other floor coverings, SA	CANSIM	5	0,47
109	PPCHA-CAN	Household appliances, SA	CANSIM	5	0,65
110	PPCSDF-CAN	Semi-durable household furnishings, SA	CANSIM	5	0,72
111	PPCNHS-CAN	Non-durable household supplies, SA	CANSIM	5	0,67
112	PPCDCC-CAN	Domestic and child care services, SA	CANSIM	5	0,37
113	PPCOHS-CAN	Other household services, SA	CANSIM	5	0,18
114	PPCMC-CAN	Medical care, SA	CANSIM	5	0,73
115	PPCHC-CAN	Hospital care and the like, SA	CANSIM	5	0,42
116	PPCOMC-CAN	Other medical care expenses, SA	CANSIM	5	0,19
117	PPCDPH-CAN	Drugs and pharmaceutical products, SA	CANSIM	5	0,71
118	PPCNUMV-CAN	New and used (net) motor vehicles, SA	CANSIM	5	0,53
119	PPCMVRP-CAN	Motor vehicle repairs and parts, SA	CANSIM	5	0,68
120	PPCMFL-CAN	Motor fuels and lubricants, SA	CANSIM	5	0,58
121	PPCOAR-CAN	Other auto related services, SA	CANSIM	5	0,19
122	PPCPT-CAN	Purchased transportation, SA	CANSIM	5	0,38
123	PPCCOM-CAN	Communications, SA	CANSIM	5	0,22
124	PPCRSC-CAN	Recreational, sporting and camping equipment, SA	CANSIM	5	0,60
125	PPCRES-CAN	Reading and entertainment supplies, SA	CANSIM	5	0,52
126	PPCRS-CAN	Recreational services, SA	CANSIM	5	0,45
127	PPCECS-CAN	Education and cultural services, SA	CANSIM	5	0,49
128	PPCPE-CAN	Personal effects not elsewhere classified, SA	CANSIM	5	0,33
129	PPCPC-CAN	Personal care, SA	CANSIM	5	0,72
130	PPCRAS-CAN	Restaurants and accommodation services, SA	CANSIM	5	0,74
131	PPCFLS-CAN	Financial and legal services, SA	CANSIM	5	0,19
132	PPCNPO-CAN	Operating expenses of non-profit organizations, SA	CANSIM	5	0,66

Gross domestic product, by industry, constant 2000 prices

	Series ID	Title	Source	Code	R^2
133	GDPBS-CAN	Business sector, goods, SA	CANSIM	5	0,90
134	GDPBSS-CAN	Business sector, services, SA	CANSIM	5	0,70
135	GDPGI-CAN	Goods producing industries, SA	CANSIM	5	0,90
136	GDPSI-CAN	Services producing industries, SA	CANSIM	5	0,68
137	GDPIP-CAN	Industrial production, SA	CANSIM	5	0,92
138	GDPAGR-CAN	Agriculture, forestry, fishing and hunting, SA	CANSIM	5	0,13
139	GDPMIN-CAN	Mining and oil and gas extraction, SA	CANSIM	5	0,29
140	GDPUT-CAN	Utilities, SA	CANSIM	5	0,46
141	GDPCON-CAN	Construction, SA	CANSIM	5	0,45
142	GDPMAN-CAN	Manufacturing, SA	CANSIM	5	0,92
143	GDPFOOF-CAN	Food manufacturing, SA	CANSIM	5	0,19
144	GDPBEV-CAN	Beverage and tobacco product manufacturing, SA	CANSIM	5	0,27
145	GDPTEX-CAN	Textile and textile product mills, SA	CANSIM	5	0,54
146	GDPCLO-CAN	Clothing manufacturing, SA	CANSIM	5	0,34
147	GDPLET-CAN	Leather and allied product manufacturing, SA	CANSIM	5	0,27
148	GDPWOOD-CAN	Wood product manufacturing, SA	CANSIM	5	0,48
149	GDPPAP-CAN	Paper manufacturing, SA	CANSIM	5	0,34
150	GDPPRI-CAN	Printing and related support activities, SA	CANSIM	5	0,35
151	GDPPET-CAN	Petroleum and coal products manufacturing, SA	CANSIM	5	0,31
152	GDPCHE-CAN	Chemical manufacturing, SA	CANSIM	5	0,54
153	GDPPL-CAN	Plastics and rubber products manufacturing, SA	CANSIM	5	0,69
154	GDPNMM-CAN	Non-metallic mineral product manufacturing, SA	CANSIM	5	0,62
155	GDPPRM-CAN	Primary metal manufacturing, SA	CANSIM	5	0,58
156	GDPFM-CAN	Fabricated metal product manufacturing, SA	CANSIM	5	0,67
157	GDPMACH-CAN	Machinery manufacturing, SA	CANSIM	5	0,57
158	GDPCEL-CAN	Computer and electronic product manufacturing, etc., SA	CANSIM	5	0,42
159	GDPTREQ-CAN	Transportation equipment manufacturing, SA	CANSIM	5	0,51

160	GDPFUN-CAN	Furniture and related product manufacturing, SA	CANSIM	5	0,57
161	GDPMISC-CAN	Miscellaneous manufacturing, SA	CANSIM	5	0,23
162	GDPWHT-CAN	Wholesale trade, SA	CANSIM	5	0,55
163	GDPRET-CAN	Retail trade, SA	CANSIM	5	0,44
164	GDPTRAN-CAN	Transportation and warehousing, SA	CANSIM	5	0,51
165	GDPINF-CAN	Information and cultural industries, SA	CANSIM	5	0,36
166	GDPFIN-CAN	Finance, insurance, real estate, etc., SA	CANSIM	5	0,16
167	GDPPR-CAN	Professional, scientific and technical services, SA	CANSIM	5	0,27
168	GDPEDUC-CAN	Educational services, SA	CANSIM	5	0,15
169	GDPHEA-CAN	Health care and social assistance, SA	CANSIM	5	0,35
170	GDPACC-CAN	Accommodation and food services, SA	CANSIM	5	0,46
171	GDPOTHS-CAN	Other services (except public administration), SA	CANSIM	5	0,39
172	GDPPA-CAN	Public administration, SA	CANSIM	5	0,14

Capacity Utilization

	Series ID	Title	Source	Code	R^2
173	CUIND-CAN	Total industrial, SA	CANSIM	5	0,87
174	CUFOR-CAN	Forestry and logging, SA	CANSIM	5	0,12
175	CUMOG-CAN	Mining and oil and gas extraction, SA	CANSIM	5	0,33
176	CUEPG-CAN	Electric power generation, transmission and distribution, SA	CANSIM	5	0,37
177	CUCON-CAN	Construction, SA	CANSIM	5	0,41
178	CUMAN-CAN	Manufacturing, SA	CANSIM	5	0,88
179	CUFOOD-CAN	Food manufacturing, SA	CANSIM	5	0,20
180	CUBEV-CAN	Beverage manufacturing, SA	CANSIM	5	0,18
181	CUTOB-CAN	Tobacco manufacturing, SA	CANSIM	5	0,11
182	CUTEX-CAN	Textiles, SA	CANSIM	5	0,51
183	CUCLO-CAN	Clothing manufacturing, SA	CANSIM	5	0,28
184	CULET-CAN	Leather and allied product manufacturing, SA	CANSIM	5	0,19
185	CUWOOD-CAN	Wood product manufacturing, SA	CANSIM	5	0,49
186	CUPAP-CAN	Paper manufacturing, SA	CANSIM	5	0,28
187	CUPRI-CAN	Printing and related support activities, SA	CANSIM	5	0,24
188	CUPET-CAN	Petroleum and coal products manufacturing, SA	CANSIM	5	0,33
189	CUCHE-CAN	Chemical manufacturing, SA	CANSIM	5	0,42
190	CUPLA-CAN	Plastic products manufacturing, SA	CANSIM	5	0,52
191	CURUB-CAN	Rubber products manufacturing, SA	CANSIM	5	0,41
192	CUNMET-CAN	Non-metallic mineral product manufacturing, SA	CANSIM	5	0,56
193	CUPMET-CAN	Primary metal manufacturing, SA	CANSIM	5	0,56
194	CUFMET-CAN	Fabricated metal product manufacturing, SA	CANSIM	5	0,62
195	CUMAC-CAN	Machinery manufacturing, SA	CANSIM	5	0,53
196	CUCOMP-CAN	Computer, electronic product, etc., SA	CANSIM	5	0,38
197	CUTRAN-CAN	Transportation equipment manufacturing, SA	CANSIM	5	0,49
198	CUFUN-CAN	Furniture and related product manufacturing, SA	CANSIM	5	0,42

Consumer and producer prices

	Series ID	Title	Source	Code	R^2
199	CPI-CAN	Consumer Price Index, all items, SA	CANSIM	5	0,87
200	CPIG-CAN	Consumer Price Index, goods, SA	CANSIM	5	0,76
201	CPIS-CAN	Consumer Price Index, services, SA	CANSIM	5	0,81
202	CPINFE-CAN	Consumer Price Index, all items excluding food and energy, SA	CANSIM	5	0,86
203	CPIF-CAN	Consumer Price Index, food , SA	CANSIM	5	0,38
204	CPIE-CAN	Consumer Price Index, energy, SA	CANSIM	5	0,64
205	PPIM-CAN	Producer Price Index, manufacturing, SA	CANSIM	5	0,75

Employment and labour costs

	Series ID	Title	Source	Code	R^2
206	UNEM-CAN	Unemployment rate, SA	OECD	1	0,65
207	EMPMIN-CAN	Employment, Total, SA	CANSIM	5	0,75
208	EMPMIN-CAN	Employment, Agriculture, SA	CANSIM	5	0,12
209	EMPMIN-CAN	Employment, Fishing , Forestry, Mining, SA	CANSIM	5	0,36
210	EMPMAN-CAN	Employment, Manufacturing, SA	CANSIM	5	0,63
211	EMPCON-CAN	Employment, Construction, SA	CANSIM	5	0,51
212	EMPSER-CAN	Employment, Services, SA	CANSIM	5	0,50
213	WAG-CAN	Hourly earnings, SA	IMF	5	0,41
214	ULC-CAN	Unit labour cost, Total economy (2005=100), SA	OECD	5	0,75
215	ULC-CAN	Unit labour cost, Industry (2005=100), SA	OECD	5	0,67
216	ULC-CAN	Unit labour cost, Manufacturing (2005=100), SA	OECD	5	0,69
217	ULC-CAN	Unit labour cost, Construction (2005=100), SA	OECD	5	0,22
218	ULC-CAN	Unit labour cost, Business services (2005=100), SA	OECD	5	0,60

Monetary and financial indcators

	Series ID	Title	Source	Code	R^2
219	MB-CAN	Monetary base, SA	IMF	5	0,22
220	M1-CAN	Monetary aggregate M1++ (gross), SA	IMF	5	0,28
221	M2-CAN	Monetary aggregate M2+ (gross), SA	IMF	5	0,61
222	M3-CAN	Monetary aggregate M3 (gross), SA	IMF	5	0,59
223	HCRED-CAN	Total household credit, SA	IMF	5	0,62

224	BCRED-CAN	Total business credit, SA	IMF	5	0,74
225	TFR-CAN	Total foreign exchange reserves, SA	CANSIM	5	0,18
226	IRBR-CAN	Bank rate	CANSIM	1	0,79
227	IRPL-CAN	Chartered bank's rate on prime loans	CANSIM	1	0,78
228	IRCPR3-CAN	Prime corporate paper rate: 3 months	CANSIM	1	0,79
229	IRTB3-CAN	Treasury Bill rate, average yield: 3 months	CANSIM	1	0,78
230	IRGCB13-CAN	Government of Canada marketable bonds, av. yield: 1-3 years	CANSIM	1	0,79
231	IRGCB35-CAN	Government of Canada marketable bonds, av. yield: 3-5 years	CANSIM	1	0,80
232	IRGCB510-CAN	Government of Canada marketable bonds, av. yield: 5-10 years	CANSIM	1	0,81
233	IRGCB10-CAN	Government of Canada marketable bonds, av. yield: over 10 years	CANSIM	1	0,81
234	SPTSX-CAN	S&P/TSX Composite Index	CANSIM	5	0,42

A.4 Figures

Figure A.1: Principal component estimates of international factors

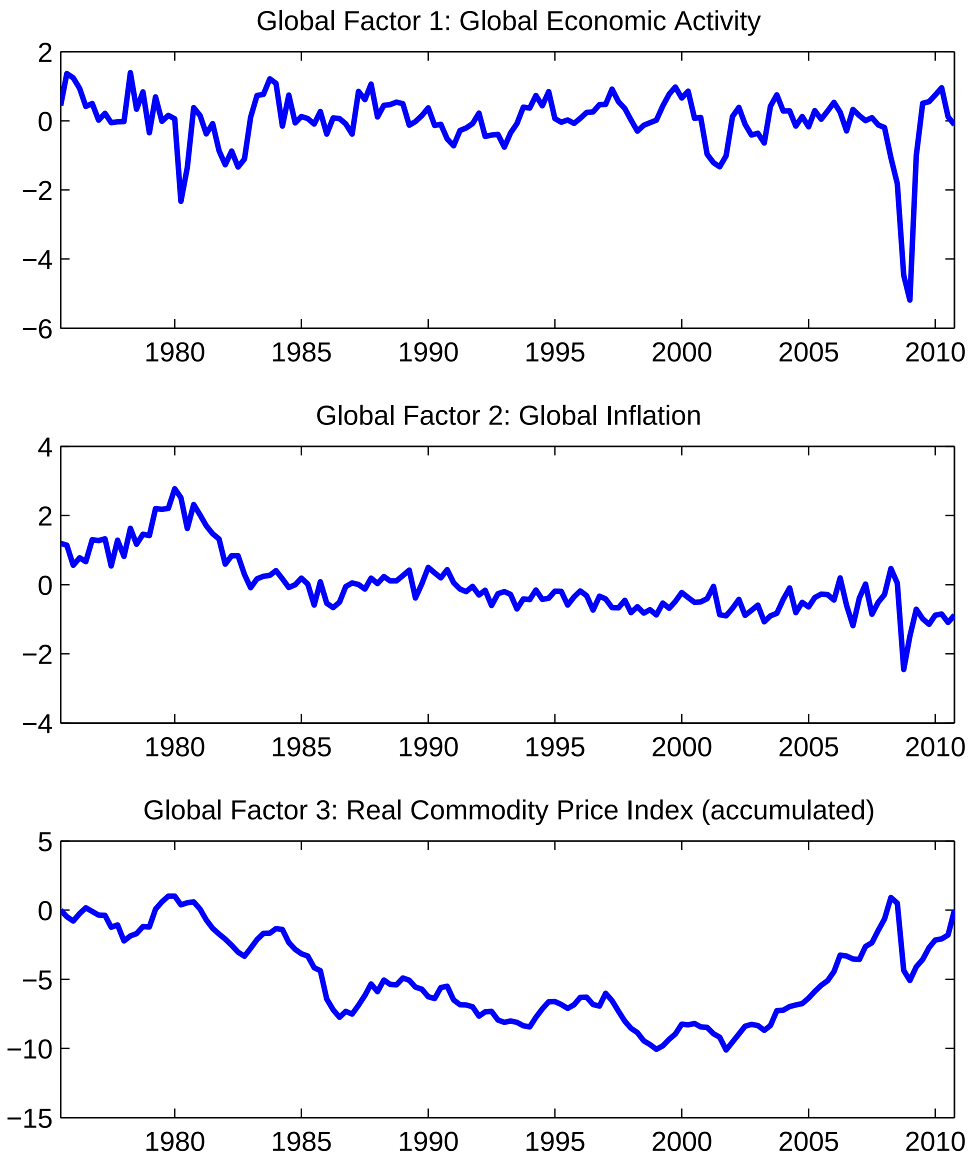
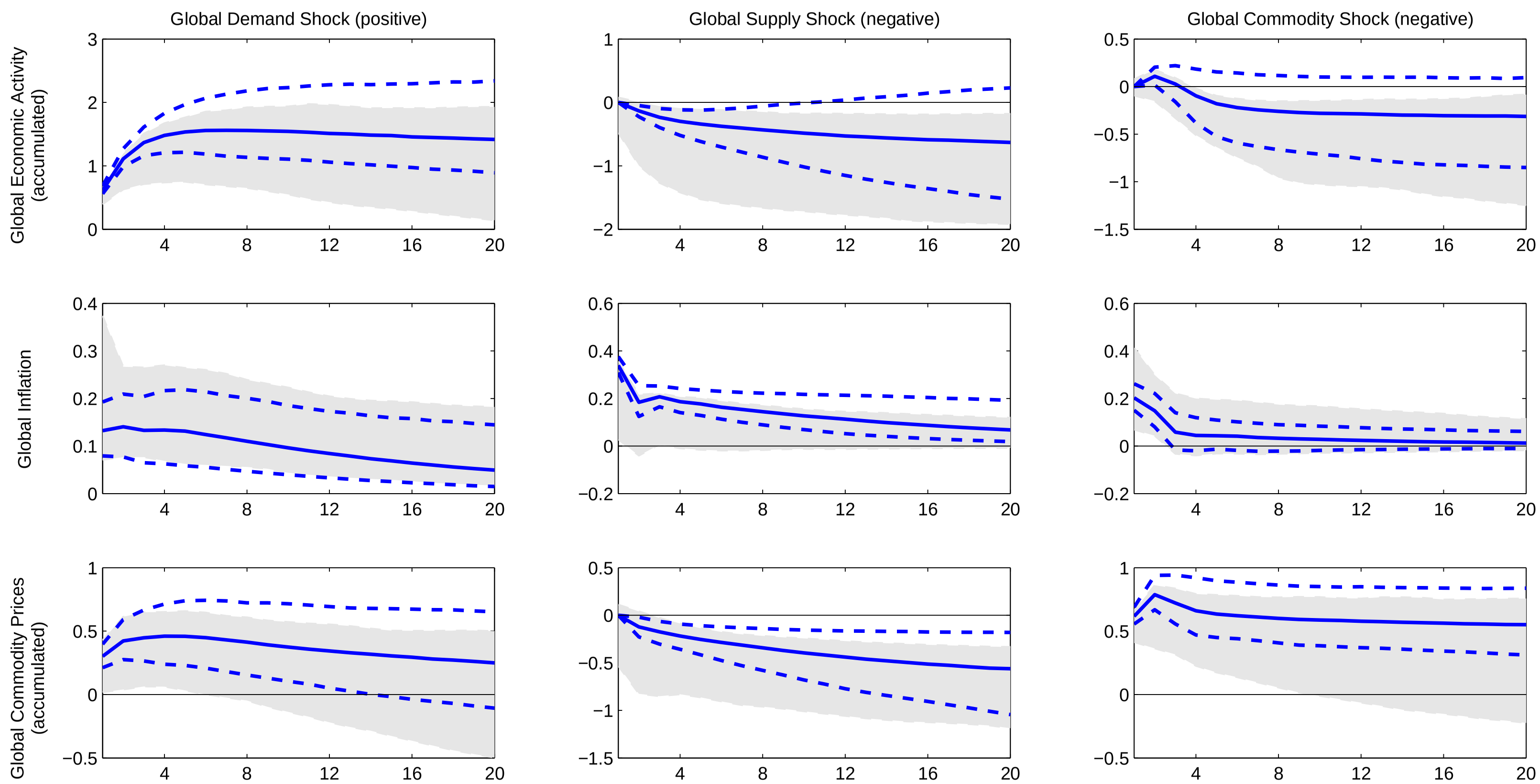


Figure A.2: Impulse responses of international factors to global shocks



recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.3: Historical decompositions of the global factors: 1975q1-2010q4

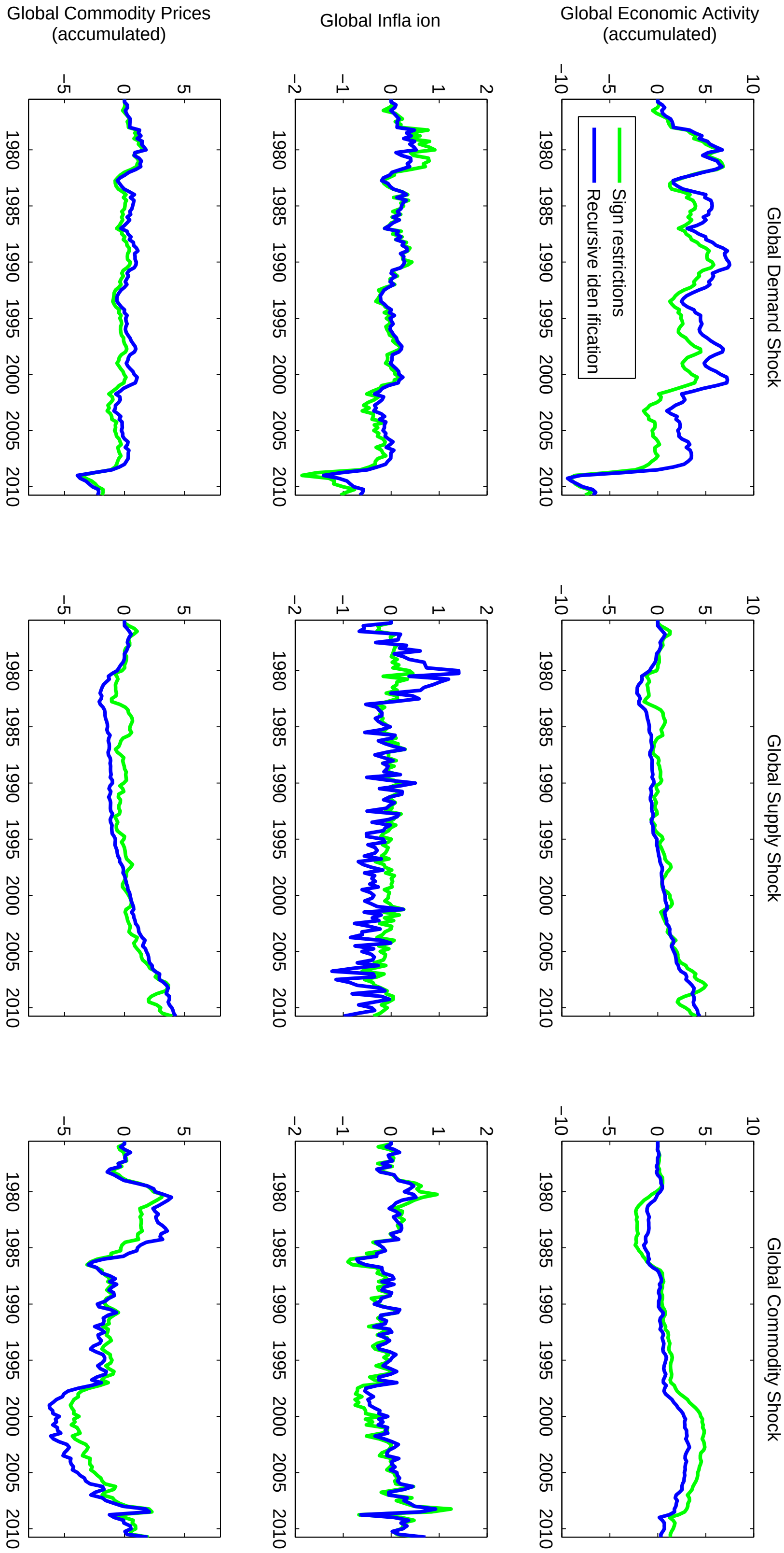
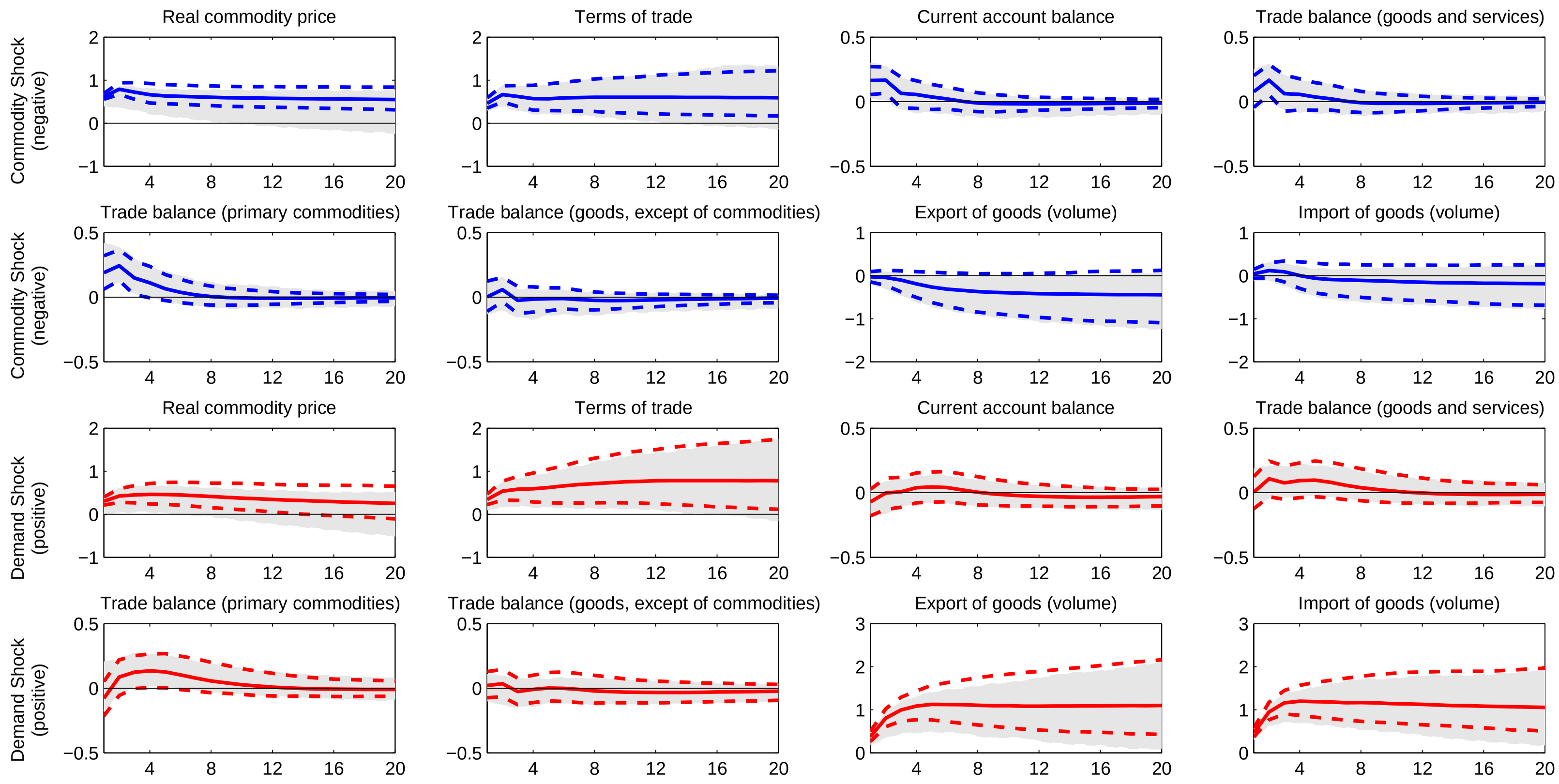
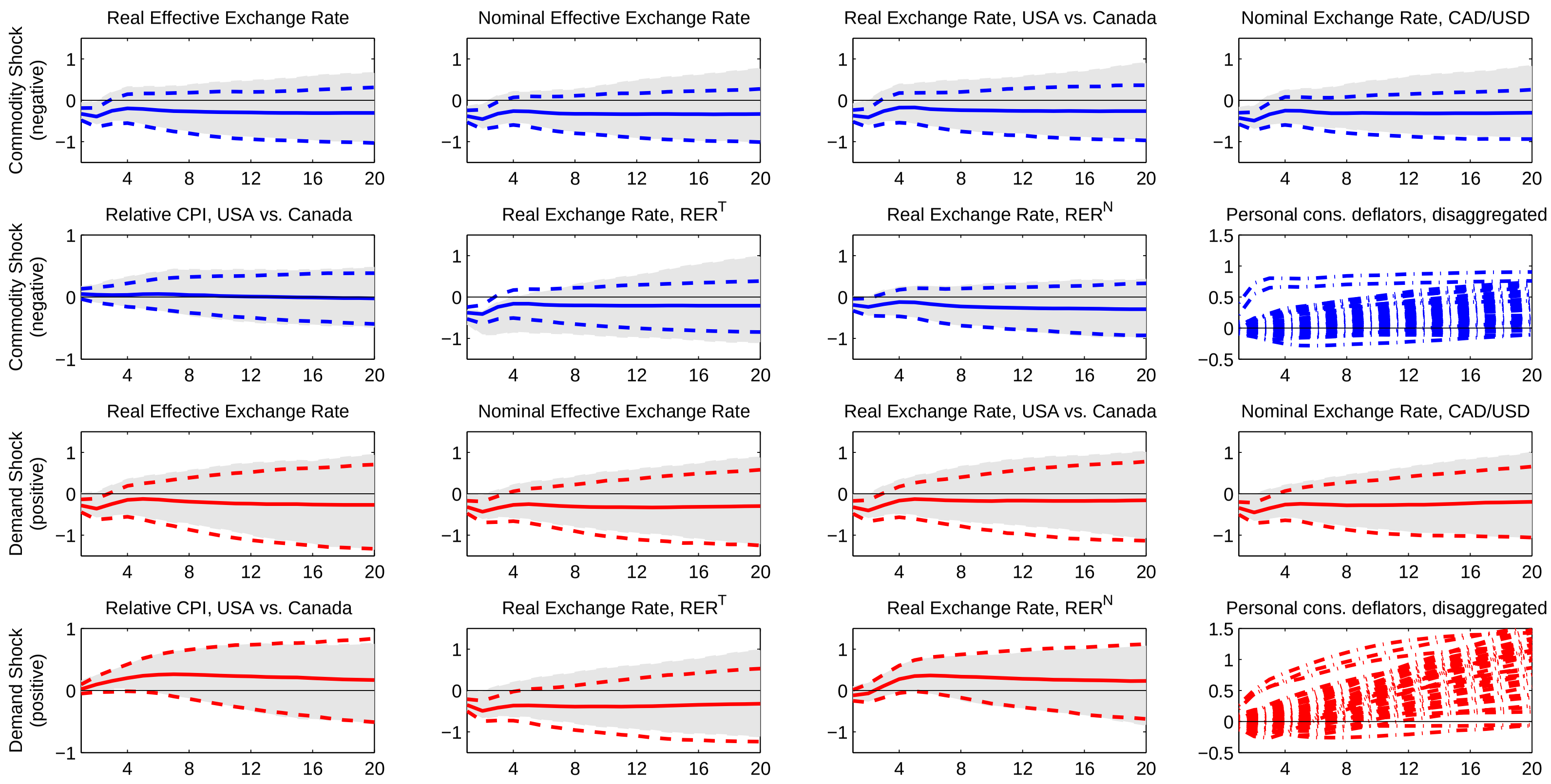


Figure A.4: Impulse responses: terms-of-trade and external balances effects



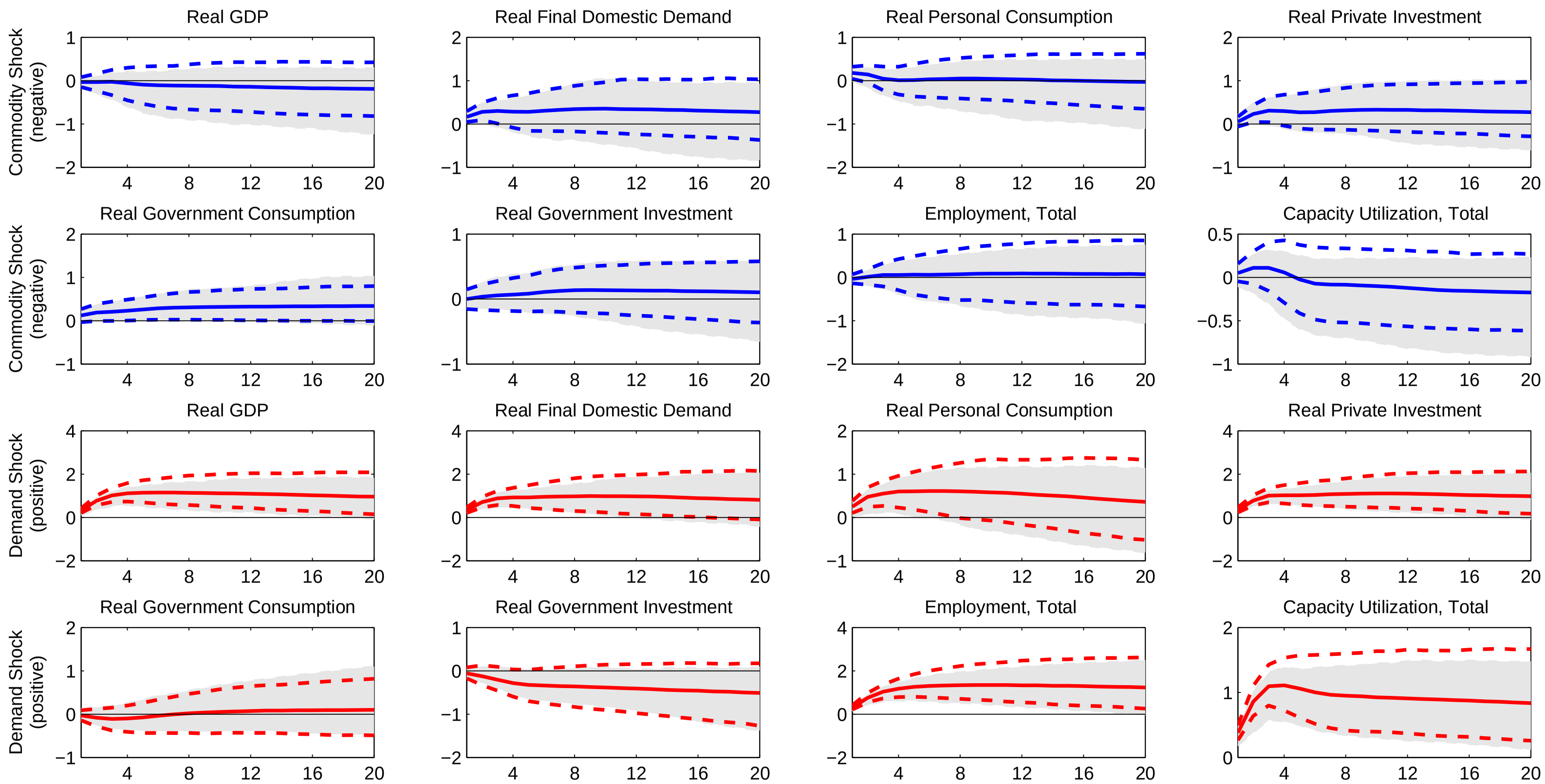
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.5: Impulse responses: commodity currency effect and relative prices



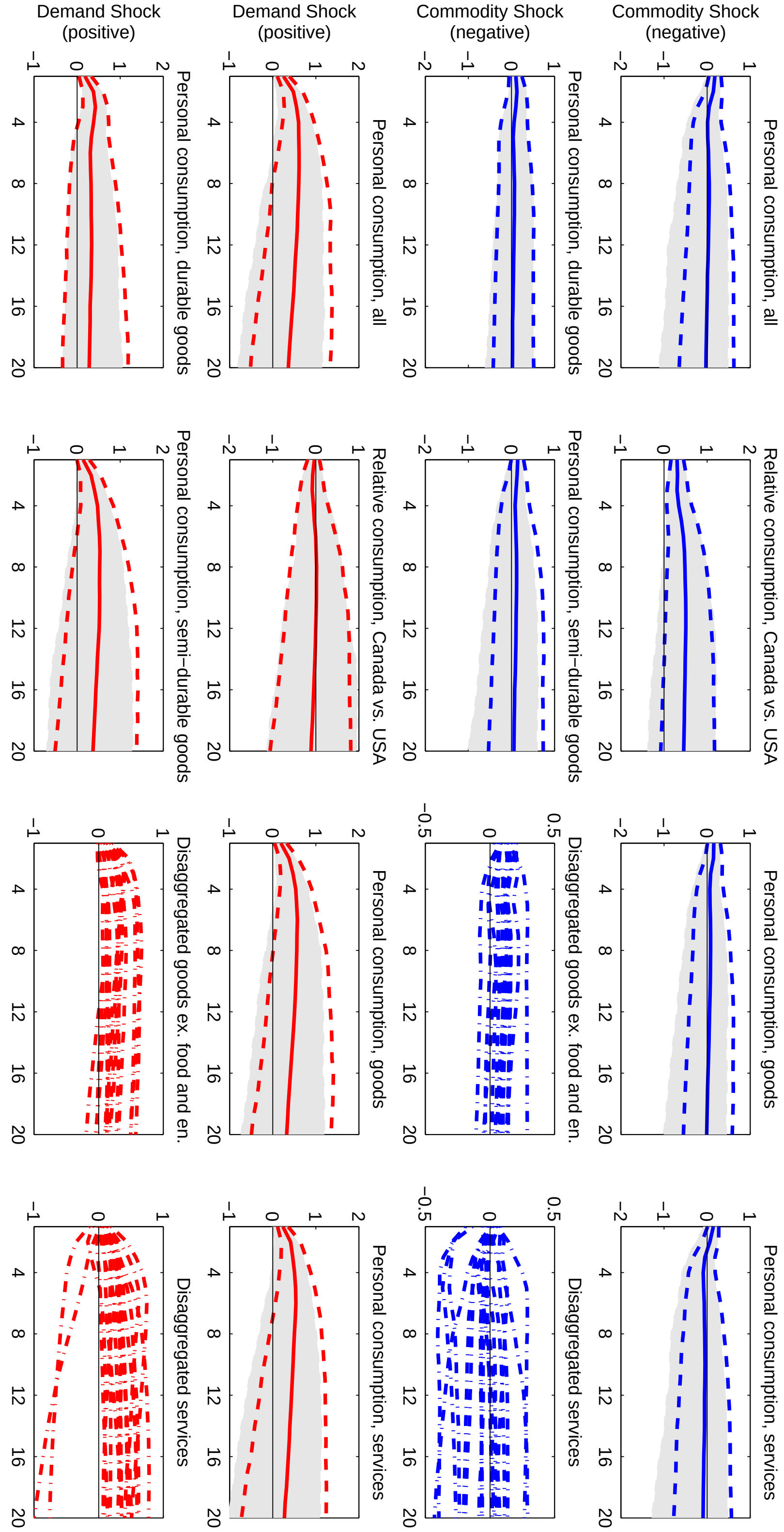
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.6: Impulse responses: output and spending effect



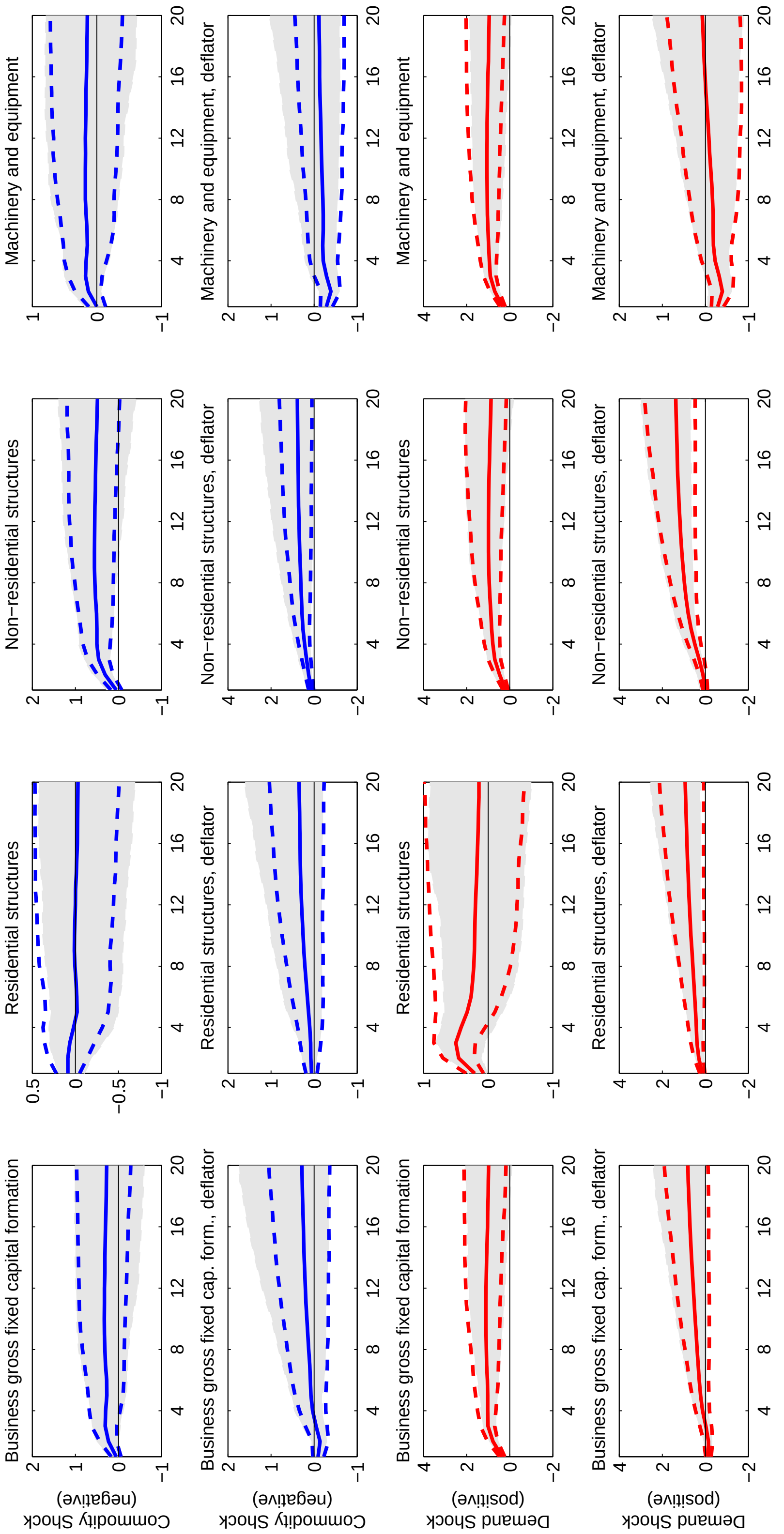
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.7: Impulse responses: personal consumption and its components



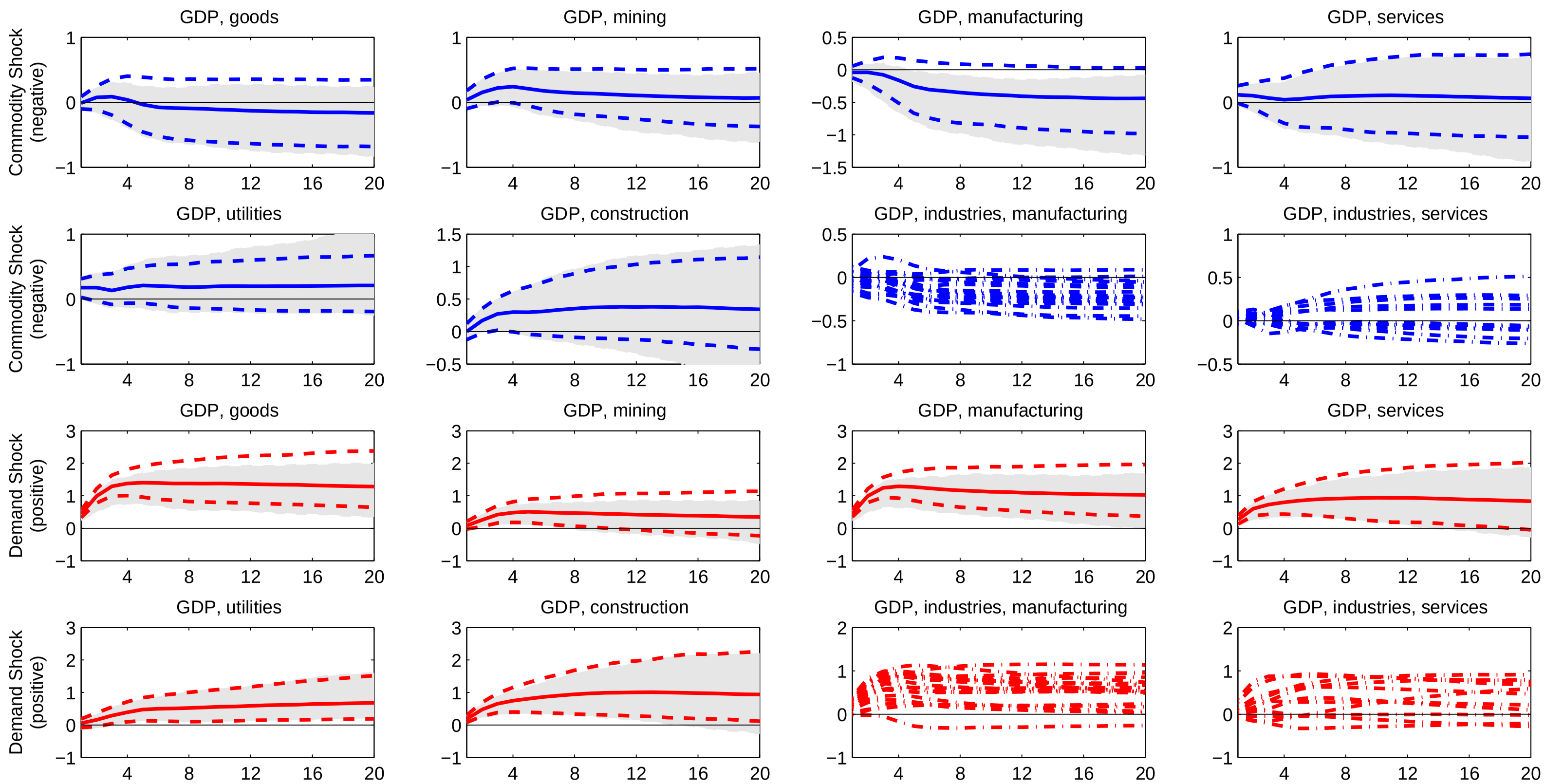
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.8: Impulse responses: investment effect



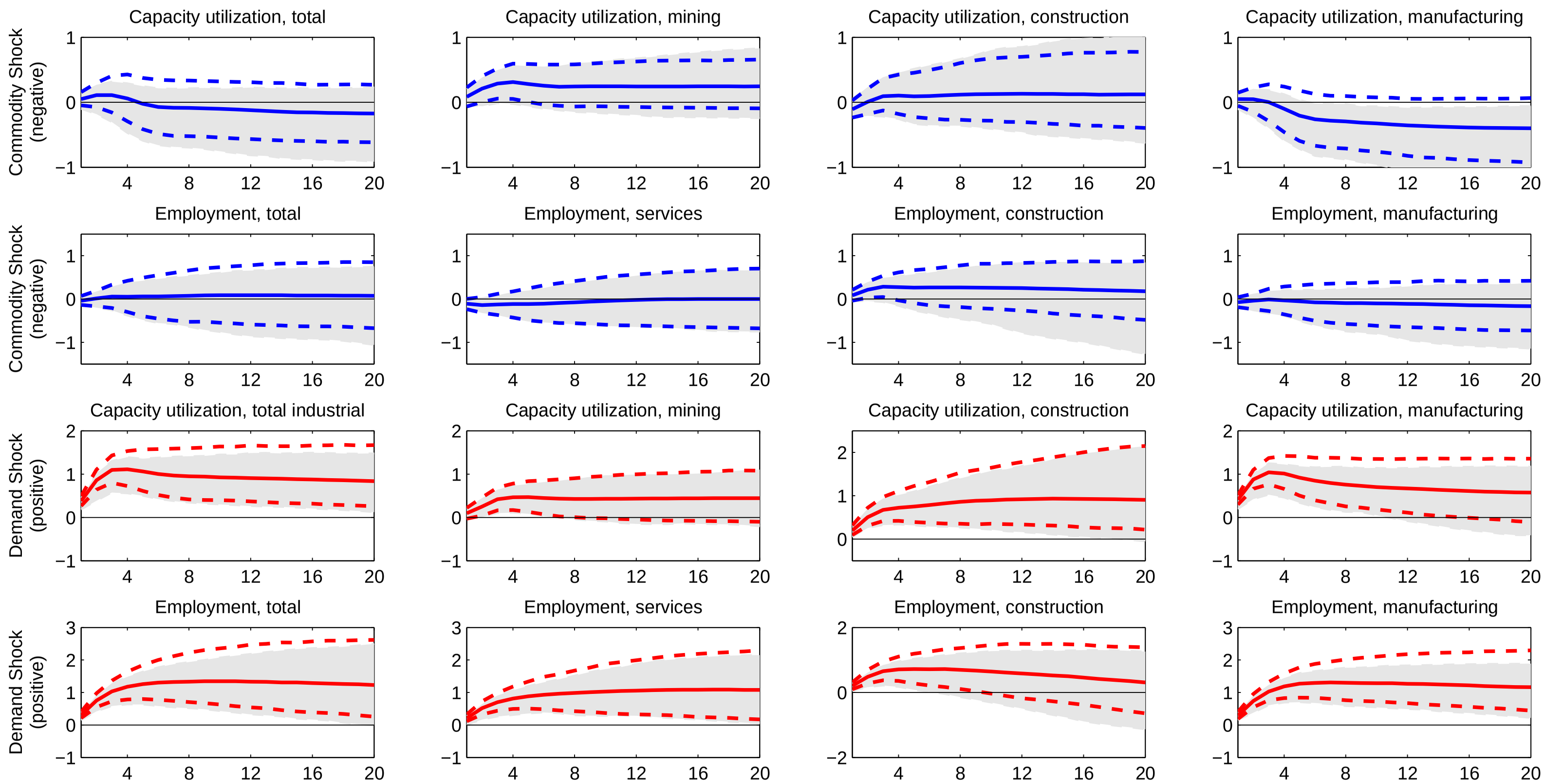
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.9: Impulse responses: GDP in industries and Dutch disease



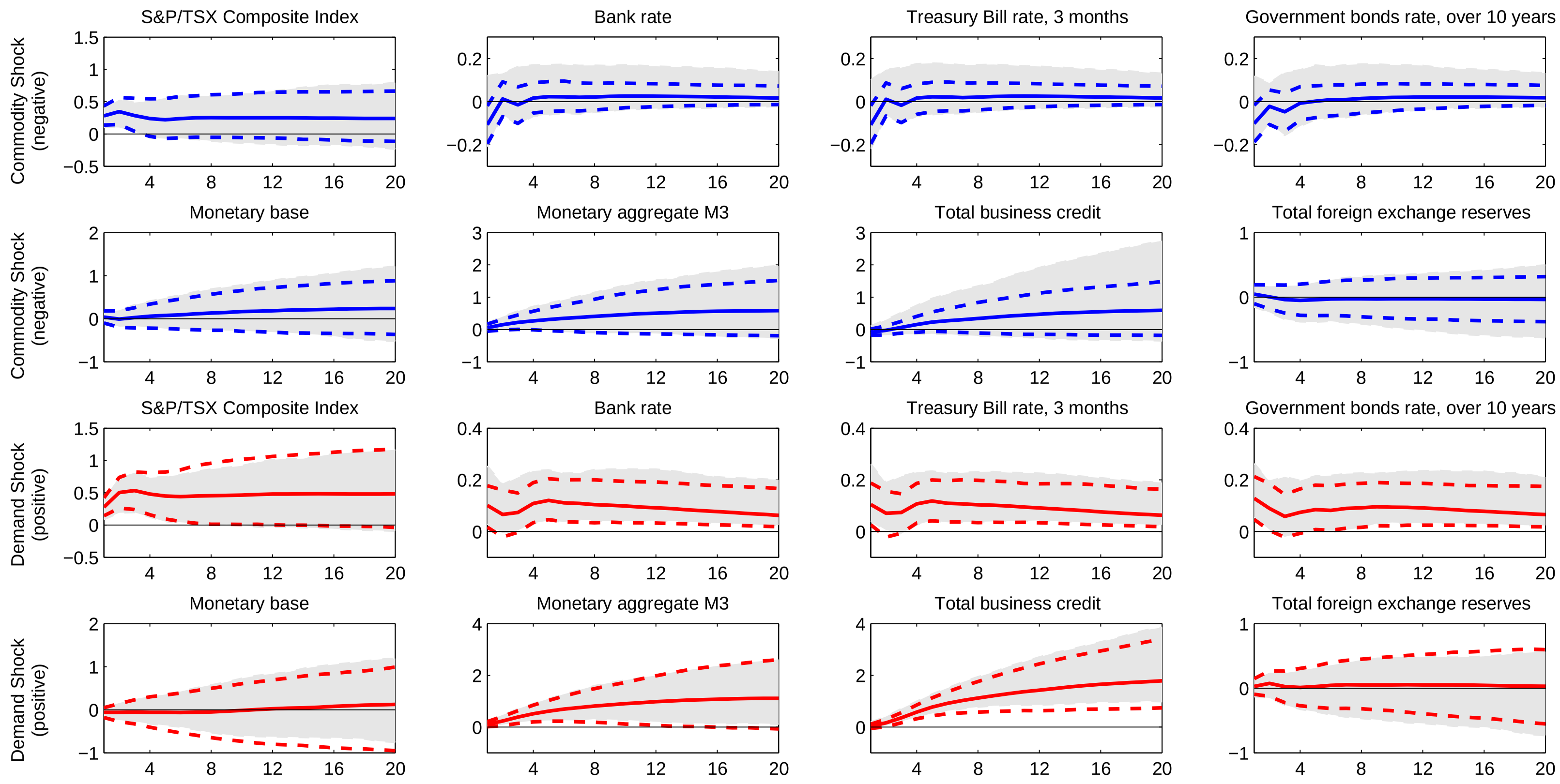
recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.10: Impulse responses: capacity utilization and employment



recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

Figure A.11: Impulse responses: monetary and financial indicators



recursive identification - solid line together with 90% credible interval; identification by sign restrictions - shaded area covering 90% credible set

A.5 Tables

Table A.2: Sectoral composition of the Canadian economy: average shares over 1985-2007

	Gross Value Added (% of total GDP)	Employment (% of total employment)	Export (% of the industry production)	Net export (% of total GDP)
Primary Commodity Sector	*7.7*	*4.8*	*36.1*	*2.8*
Agriculture, forestry and fishing	2.6	3.7	23.0	0.6
Mining and quarrying	5.1	1.1	45.9	2.2
Tradable Sector	*17.5*	*14.6*	*46.9*	*-0.7*
Manufacturing	17.5	14.6	46.9	-0.7
Non-tradable Sector	*74.7*	*80.5*	*4.3*	*-1.0*
Utilities	3.0	0.8	5.1	0.1
Construction	5.8	6.1	-	-
Services	65.9	73.7	4.8	-1.1

Data: OECD STAN database, CANSIM Canada, average over 1985-2007

Table A.3: Business cycles in Canada: 1985q1-2010q4

	Volatility (% per quarter)	Correlation with GDP	Cross-correlations with (leads/lags of) real commodity price								
			lags					leads			
			-6	-4	-2	-1	0	1	2	4	6
GDP	1.30	1.00	-0.34	-0.27	0.18	0.35	0.43	0.43	0.38	0.20	0.03
primary commodity sector	2.27	0.51	-0.47	-0.29	0.29	0.43	0.35	0.19	0.10	0.04	0.05
tradable sector	3.68	0.91	-0.45	-0.33	0.13	0.35	0.48	0.48	0.40	0.17	0.03
nontradable sector	0.98	0.90	-0.22	-0.21	0.14	0.32	0.43	0.42	0.35	0.19	0.02
Consumption	0.98	0.79	-0.10	-0.07	0.15	0.27	0.41	0.45	0.34	0.01	-0.11
Investment	4.82	0.69	-0.17	-0.12	0.18	0.34	0.38	0.29	0.18	0.00	-0.07
Employment	0.88	0.74	-0.21	-0.06	0.28	0.41	0.44	0.37	0.27	0.10	0.00
Government purchases	1.11	-0.10	-0.08	-0.13	-0.11	-0.06	-0.05	-0.10	-0.15	-0.09	-0.01
Net export (% of GDP)	0.94	0.32	-0.13	-0.12	0.28	0.47	0.60	0.52	0.31	0.13	0.00
Real exchange rate	4.01	-0.12	-0.03	-0.03	-0.09	-0.19	-0.28	-0.31	-0.22	0.15	0.34
Real commodity price	9.10	0.43	-0.17	-0.12	0.28	0.71	1.00	0.71	0.28	-0.12	-0.17
GDP in United States	1.10	0.81	-0.29	-0.27	0.03	0.21	0.37	0.41	0.34	0.09	-0.02

Data sources: CANSIM Canada, OECD; sample period is 1985:1-2010:4; all variables except net export are in logarithms; all variables are filtered with HP-filter; primary commodity sector - agriculture, forestry and fishing, mining and quarrying; tradable sector - manufacturing; nontradable sector - utilities, construction, services.

Chapter 2

Commodity price shocks and real business cycles in a small commodity-exporting economy

2.1 Introduction

The share of primary commodities in world output and trade has declined over the last century. Nevertheless, fluctuations in commodity prices still significantly affect economic activity, especially in countries, where primary commodities remain a main source of export earnings. In these countries commodity price movements have enormous impacts on real output, exchange rates, balance of payments and public finance, and, as a result, pose serious problems for the conduct of macroeconomic policy.

The economic literature emphasizes several important stylized facts regarding the effects of commodity price changes on business cycles in commodity-exporting economies. These facts have been described in detail in Chapter 1 and can be summarized here as follows. First, real commodity prices are positively correlated with trade and current account balances (*external balances effect*). Second, real exchange rates are highly volatile and exhibit a negative correlation with the real commodity price, so that increasing commodity price results in an appreciation of the real exchange rate (*commodity currency effect*). Third, relative consumption between commodity-exporting economy and its trade partners is negatively correlated with the real exchange rate, invalidating predictions of the many international business cycles models with perfect financial markets (*Backus-Smith puzzle*). Fourth, an increase in commodity export revenues is associated with a decline in the non-commodity tradable sector (*Dutch disease*). And, finally, there is a positive effect of the real commodity price on investment (*investment effect*).

A range of the models have been proposed in the economic literature to explain the effects of the world commodity price (and/or terms-of-trade) shocks on business cycles in a small commodity-exporting economy, starting from the early deterministic analysis of Dutch disease in Corden and Neary (1982) and Bruno and Sachs (1982). So, for example, Mendoza (1995) analyses the quantitative importance of terms of trade shocks in driving business cycles using a dynamic stochastic small open economy model. Kose (2002) extends Mendoza's work by developing a richer production structure that captures several empirically relevant features of developing economies. Sosunov and Zamulin (2007) and Dib (2008) study monetary policy in resource rich economies, in application to Russia and Canada respectively. These recent models are constructed in the line with new open economy macroeconomics paradigm and feature a small open economy structure, multiply goods, exogenous world commodity price shocks and one non-risky internationally traded asset. However, they have several drawbacks.

First, the world economy is often not modeled explicitly. The foreign variables, such as real commodity price, terms of trade, world interest rate and world output, are usually introduced as exogenous stochastic shocks. Interrelations between these extraneous variables are either imposed using the variance-covariance matrix or not specified at all. However, this approach may be misleading, given that the world prices and interest rates are not shocks per se. These variables reflect endogenous responses of the world economy to many distinct supply and demand shocks. As it has been shown in Chapter 1, despite some of these world-wide shocks increase commodity prices, their overall effects on a small commodity-exporting economy may be completely different.

Second, in these models there is usually only one non-risky internationally traded asset. However, an assumption of incomplete markets in a stochastic small open economy model results in steady-state equilibrium that depends on initial conditions and equilibrium dynamics that possess a random walk component. To induce a stationarity standard models usually assume non-separable preferences or some form of frictions in assets trade (Schmitt-Grohe and Uribe, 2003). But these additional elements, without an assumption of incomplete markets itself, may be responsible for generating many stylized facts in aforementioned models. Indeed, as Chari, Kehoe, and McGrattan (2002) show, the models with incomplete markets and without other frictions fail to solve Backus-Smith and exchange rate volatility puzzles. Besides, their dynamics is close to those generated by the models with complete markets.[1] So, an assumption of incomplete markets is not very crucial and working with complete markets may be more convenient.

In this chapter I propose a new real business cycles model of a small commodity-exporting economy explaining simultaneously the five stylized facts regarding this economy. In contrast to the existing literature, the foreign (world) economy is modeled ex-

[1]Benigno and Thoenissen (2007) show that a model with incomplete markets and nontradable intermediate goods can solve Backus-Smith puzzle, though it fails to generate volatile real exchange rate. Therefore, in this chapter I report also impulse responses for the model with incomplete markets. Simulations show that dynamics of this model are very close to those in the model with complete markets. That is in the line with results of Chari et al. (2002).

plicitly, so all the world prices are determined endogenously in response to the global productivity and commodity endowment shocks. That allows also to control explicitly cross-country risk-sharing. The only key difference between home and foreign economies is in different productivity levels in tradable, nontradable and commodity sectors, such that home economy appears to be relatively abundant in primary commodities.

In the initial version of the model I assume complete assets markets and no frictions in intertemporal trade. This model generates a positive correlation between commodity price and trade balance, but cannot reproduce volatile and negatively correlated with the real commodity price real exchange rate. Moreover, relative consumption moves in lockstep with the real exchange rate, illustrating Backus-Smith puzzle. In this model international risk sharing is working well and frictions in intratemporal trade are not high enough to induce significant volatility in the real exchange rate. Besides, in this model there is no manifestation of Dutch disease and investment effect.

Next, the opposite case will be considered, when home country has no access to financial markets but intratemporal trade is allowed (financial autarky). Because international risk sharing via trade in financial assets is not possible, commodity price shocks induce very volatile real exchange rate, which is negatively correlated with commodity prices and relative consumption. This model also predicts Dutch disease and investment effect. Nevertheless, assumption of financial autarky is too strict and contradicts observable fluctuations in trade balances.

To increase a volatility of the real exchange rate and to damp risk sharing in the model with complete markets I need to break link between marginal rate of substitution in consumption across countries and real exchange rate. There are several ways to do it.

The first approach is to introduce occasionally binding borrowing constraints. These constraints may be exogenous, given, for example, by the rule which prevents country to borrow or save beyond some limits. It is possible also to model these constraints endogenously, assuming a limited enforcement of international contracts, as in Alvarez and Jermann (2000), Kehoe and Perri (2002) and Bodenstein (2008).[2]

The second strategy is to assume some kind of frictions in assets trade. For example, agents may face convex costs of holding assets in quantities different from some long-run level as in (Schmitt-Grohe and Uribe, 2003).[3]

[2]In the model of a small open economy two-sided limited commitment is not possible, because the value of autarky for foreign economy coincides with the value of intertemporal trade. The case of one-sided limited commitment is not very interesting, since small economy can effectively achieve risk sharing under full commitment by accumulating assets, which would be seized in the case of default (see Itskhoki, 2007).

[3]An alternative way to break link between relative consumption and real exchange rate and to increase volatility of the real exchange rate without introduction of frictions in assets trade is to relax an assumption of additive separable preferences. Nonseparable preferences create wedge between relative consumption and cross-country marginal rate of substitution of consumption, though the latter is still equal to the real exchange rate. For example, Verdelhan (2010) discusses this effect using habit-based preferences.

The last strategy is applied in this chapter. To adjust the value of portfolio of international assets, the home households have to bear transaction costs. This model succeeded to replicate all aforementioned stylized facts about commodity-exporting economies.

The rest of the chapter is organized as follows. Section 2 provides an empirical evidence regarding the effects of the real commodity price changes on business cycles in selected commodity-exporting countries. Section 3 presents the model of a small commodity-exporting economy. Section 4 discusses calibration and computational algorithm. Section 5 reports the main results. Section 6 concludes.

2.2 An empirical evidence

In this section, I briefly discuss an empirical evidence about business cycles in selected commodity-exporting countries. I focus here on four developed resource rich countries, data of which are abundant: Australia, Canada, Norway and New Zealand.[4]

Figures B.1-B.2 illustrate some stylized facts regarding business cycles in these countries. The upper part of these figures shows a relationship between the effective real exchange rate and relative consumption.[5] The middle part illustrates dynamics of the real commodity price[6] and the effective real exchange rate. And finally, the lowest part shows the trade balance (as share of GDP) and the real commodity price index. Table B.1 summarizes the second moments of data for these countries, computed both for the levels and for the HP-filtered series. Data are presented both for the period of 1970-2008 and for the less turbulent sub-period of 1985-2008. In what follows, I will discuss the results for the HP-filtered series.

As the table shows, the real commodity price index is very volatile. Its standard deviation varies from 7.95% in New Zealand to 14.16% in Norway. The effective real exchange rates are also highly volatile and negatively correlated with the real commodity prices, illustrating the commodity currency effect. This negative correlation is more apparent for the recent period of 1985-2008 and is more pronounced for Australia and New Zealand. These countries also manifest the highest standard deviations of the real exchange rate.

The real commodity prices are positively correlated with trade balance (at least for the period of 1985-2008) and investment (except of Norway). The data illustrate appar-

[4]According to the UN COMTRADE database, top three exported primary commodities (two-digits) in 2007 for these countries were as follows (a share in total export is reported). Canada: petroleum, petroleum products and related materials - 12.5%, gas, natural and manufactured - 7%, non-ferrous metals - 5.4%. Australia: metalliferous ores and metal scrap - 20.5%, coal, coke and briquettes - 12.4%, non-ferrous metals - 8.1%. Norway: petroleum, petroleum products and related materials - 44.6%, gas, natural and manufactured - 19.3%, non-ferrous metals - 7.7%. New Zealand: dairy products and birds' eggs - 20.6%, meat and meat preparations - 12.1%, vegetables and fruit - 5.3%.

[5]Relative consumption is computed against the country or block of countries with the highest share of mutual trade: Canada vs. US, Australia vs. OECD, Norway vs. EU and New Zealand vs. Australia.

[6]The real commodity price is computed as a price index of exported primary commodities (in US dollars) deflated by the consumer price index in the United States.

ently the Backus-Smith puzzle. Moreover, for Canada, Australia and New Zealand the correlation between the real exchange rate and relative consumption is negative for the recent data.

The most interesting pattern is shown by the Norway's data. Though the real commodity price index in this country is the most volatile in my sample, its effective real exchange rate has the lowest standard deviation.[7] Besides, a negative correlation between the real exchange rate and commodity prices is not very strong, -0.14, comparing to -0.41 in Australia. Investment in Norway is negatively correlated with the real commodity price index, which is in contrast to other developed commodity-exporting countries where this correlation is positive. Trade balance is closely linked with the real commodity price. Consumption differential with the EU is not correlated with the real exchange rate. In addition, for the most recent data this correlation is positive, that is closer to unitary value predicted by the international business cycle models with perfect financial markets. As this chapter shows, all these facts may indicate about the better functioning of international risk sharing in Norway comparing to other countries considered in this section.

2.3 The model

This section presents a real business cycle model of a small commodity-exporting economy. The model is introduced in three steps. First, I discuss a general theoretical framework for modeling the world economy as a continuum of small open economies. Then, specific assumptions about productivities and commodity endowments will be made to reduce this general model to the more tractable two-country model, where the first region corresponds to a small commodity-exporting economy whereas the second one to the global economy as a whole. And, finally, I will discuss three alternative variants of this simplified model under the different assumptions about the extent of risk-sharing between these two regions, namely i) the model with complete markets, ii) the model of financial autarky and iii) the model with financial transaction costs.

Notation is as follows. Variables with an i subscript refer to economy i, one among the continuum of economies making up the world economy. Variables without an i-index denote a small commodity-exporting economy being modelled. Finally, variables with a star superscript correspond to the world economy as a whole (typical foreign economy).

[7] Norway exports mainly energy resources, prices of which are the most volatile among the primary commodities.

2.3.1 General description of the model

The world economy is modeled as a continuum of small open economies represented by unit interval, as in Gali and Monacelli (2005). All economies have the same preferences, technology and market structure. Assets markets are complete.

A typical small economy produces three types of good: differentiated *tradable* good, differentiated *nontradable* good and homogeneous primary *commodity*. Tradable goods can be used for consumption and investment either in domestic economy or abroad, whereas nontradable goods can be invested or consumed only in domestic country. Commodity can be consumed, exported or used along with labor and capital as an input in production of tradable and nontradable goods. The firms producing tradable and nontradable goods and commodity endowments are owned by the domestic households.

The world economy is affected by the productivity shocks in tradable and nontradable sectors as well as by the commodity endowments shocks.

2.3.2 Households

A typical small economy i is inhabited by representative household, which maximizes expected life-time utility:

$$\max_{\{c_t, l_t, a_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t(i), 1 - l_t(i)\right) \tag{2.1}$$

subject to a sequence of budget constraints expressed in units of domestic consumption good:

$$c_t(i) + \int_{s_{t+1}} q_{t,t+1}(s_{t+1}, i) a_{t+1}(s_{t+1}, i) ds_{t+1} \leq a_t(i) + w_t(i) l_t(i) + \Pi_t(i) \tag{2.2}$$

where c_t is a composite consumption good, l_t denotes hours worked, w_t is a real wage, a_{t+1} are holdings of the Arrow-Debreu securities, priced at $q_{t,t+1}$, Π_t denotes profits from the domestic firms and commodity endowment. All prices are given in terms of domestic consumption and can be converted into prices in terms of consumption in country j trough division by bilateral real exchange rate $e_t(i,j)$ (the price of consumption good in j in terms of consumption in country i).[8] The problem is supplemented with a natural borrowing constraint to avoid Ponzi schemes.

The composite consumption good c_t is a CES basket of the tradable $c_{T,t}$, nontradable

[8]So, an increase in bilateral real exchange rate $e_t(i,j)$ reflects depreciation of the real exchange rate in country i and respectively its appreciation in country j. No arbitrage implies that $e_t(i,j) = e_t(j,i)^{-1}$ and $e_t(i,j)e_t(j,k) = e_t(i,k)$.

$c_{N,t}$ goods and commodity $c_{X,t}$:

$$c_t(i) = \left(\alpha_{CT}^{\frac{1}{\epsilon}} c_{T,t}^{\frac{\epsilon-1}{\epsilon}}(i) + \alpha_{CN}^{\frac{1}{\epsilon}} c_{N,t}^{\frac{\epsilon-1}{\epsilon}}(i) + (1-\alpha_{CT}-\alpha_{CN})^{\frac{1}{\epsilon}} c_{X,t}^{\frac{\epsilon-1}{\epsilon}}(i)\right)^{\frac{\epsilon}{\epsilon-1}} \tag{2.3}$$

where ϵ denotes an elasticity of substitution between tradable and nontradable goods (with $\epsilon < 1$) and α_{CT} and α_{CN} reflect the weights of tradable and nontradable goods in composite index.

The index of tradable goods $c_{T,t}$ is in turn a CES basket of the home $c_{H,t}$ and foreign $c_{F,t}$ tradable goods:

$$c_{T,t}(i) = \left(\alpha_{CH}^{\frac{1}{\theta}} c_{H,t}^{\frac{\theta-1}{\theta}}(i) + (1-\alpha_{CH})^{\frac{1}{\theta}} c_{F,t}^{\frac{\theta-1}{\theta}}(i)\right)^{\frac{\theta}{\theta-1}} \tag{2.4}$$

where θ is an elasticity of substitution between home and foreign tradable goods (with $\epsilon < \theta$) and α_{CH} reflects the home bias in consumption of tradable goods.

Foreign tradable good $c_{F,t}$ is an aggregate of all imported tradable goods:

$$c_{F,t}(i) = \left(\int_0^1 c_{F,t}^{\frac{\theta-1}{\theta}}(i,j)dj\right)^{\frac{\theta}{\theta-1}} \tag{2.5}$$

Households allocate their consumption by solving expenditure minimization problem (taking prices of goods as given).

2.3.3 Firms

The markets for all goods in the model are perfectly competitive. All the firms and commodity endowments are assumed to be owned by domestic households. Technology in tradable and nontradable sectors is symmetric across the world.

A typical firm producing nontradable good has the following production function:

$$y_{N,t}(i) = \left((1-\phi_N)^{\frac{1}{\xi}} \left(A_{N,t}(i) k_{N,t}^{\beta_{NK}}(i) l_{N,t}^{1-\beta_{NK}}(i)\right)^{\frac{\xi-1}{\xi}} + \phi_N^{\frac{1}{\xi}} x_{N,t}^{\frac{\xi-1}{\xi}}(i)\right)^{\frac{\xi}{\xi-1}} \tag{2.6}$$

where $A_{N,t}$ is a productivity in the nontradable sector, $k_{N,t}$, $l_{N,t}$ and $x_{N,t}$ are capital, labor and commodity inputs, ξ is elasticity of substitution between value added and commodity input and ϕ_N denotes share of commodity input in the total costs of nontradable firm.

This firm maximizes the expected discounted value of profits:

$$\max_{\left\{k_{N,t+1}, l_{N,t}, x_{N,t}, i^d_{N,t}\right\}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{U_c\left(c_t(i), 1-l_t(i)\right)}{U_c\left(c_0(i), 1-l_0(i)\right)} \Pi_{N,t}(i) \tag{2.7}$$

with profits $\Pi_{N,t}$ determined as:

$$\Pi_{N,t}(i) = p_{N,t}(i)y_{N,t}(i) - p_{I,t}(i)i^d_{N,t}(i) - w_t(i)l_{N,t}(i) - p_{X,t}(i)x_{N,t}(i) \tag{2.8}$$

where $p_{N,t}$, $p_{I,t}$ and $p_{X,t}$ denote prices of nontradable good, investment and commodity respectively.

Maximization is subject to constraints imposed by the production function (2.6) and by the following capital transition equation:

$$k_{N,t+1}(i) = (1-\delta)k_{N,t}(i) + k_{N,t}(i)\Psi_k\left(\frac{i^d_{N,t}(i)}{k_{N,t}(i)}\right) \tag{2.9}$$

where δ is depreciation rate and $i^d_{N,t}$ denotes new investment into nontradable sector with installation costs determined by function $\Psi_k(\cdot)$.[9] The capital adjustment costs are introduced into this model to avoid excessive equilibrium volatility of investment. An initial capital stock in nontradable sector $k_{N,0}(i)$ is given.

A typical firm in tradable sector solves a similar problem. It maximizes the expected discounted value of lifetime profits:

$$\max_{\left\{k_{T,t+1}, l_{T,t}, x_{T,t}, i^d_{T,t}\right\}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{U_c\left(c_t(i), 1-l_t(i)\right)}{U_c\left(c_0(i), 1-l_0(i)\right)} \Pi_{T,t}(i) \tag{2.10}$$

with profits $\Pi_{T,t}$ determined as:

$$\Pi_{T,t}(i) = p_{H,t}(i)y_{T,t}(i) - p_{I,t}(i)i^d_{T,t}(i) - w_t(i)l_{T,t}(i) - p_{X,t}(i)x_{T,t}(i) \tag{2.11}$$

where $k_{T,t}$, $l_{T,t}$ and $x_{T,t}$ are capital, labor and commodity inputs and $p_{H,t}$ is price of domestic tradable good.

Maximization is constrained by the production function and capital transition equation:

$$y_{T,t}(i) = \left((1-\phi_T)^{\frac{1}{\xi}}\left(A_{T,t}(i)k_{T,t}^{\beta_{TK}}(i)l_{T,t}^{1-\beta_{TK}}(i)\right)^{\frac{\xi-1}{\xi}} + \phi_T^{\frac{1}{\xi}} x_{T,t}^{\frac{\xi-1}{\xi}}(i)\right)^{\frac{\xi}{\xi-1}} \tag{2.12}$$

$$k_{T,t+1}(i) = (1-\delta)k_{T,t}(i) + k_{T,t}(i)\Psi_k\left(\frac{i^d_{T,t}(i)}{k_{T,t}(i)}\right) \tag{2.13}$$

where $A_{T,t}$ is a productivity in the tradable sector, ϕ_T is share of commodity input in total costs of tradable firm, δ is depreciation rate and $i^d_{T,t}$ denotes new investment into tradable sector with installation costs $\Psi_k(\cdot)$. An initial capital stock in tradable sector $k_{T,0}(i)$ is given.

[9]Capital adjustment costs function $\Psi_k(\cdot)$ has to satisfy the following properties in the steady state: $\Psi_k(\delta) = \delta$, $\Psi'_k(\delta) = 1$ and $\Psi''_k(\delta) = d < 0$.

Investment good i_t is a CES basket of the tradable $i_{T,t}$ and non-tradable $i_{N,t}$ goods:

$$i_t(i) = \left(\alpha_{IT}^{\frac{1}{\epsilon}} i_{T,t}^{\frac{\epsilon-1}{\epsilon}}(i) + (1-\alpha_{IT})^{\frac{1}{\epsilon}} i_{N,t}^{\frac{\epsilon-1}{\epsilon}}(i)\right)^{\frac{\epsilon}{\epsilon-1}} \tag{2.14}$$

where α_{IT} reflects the weight of tradable goods in composite investment index. It is assumed that the share of tradable goods in investment is higher comparing to consumption, so $\frac{\alpha_{IT}}{\alpha_{CT}} > \frac{\alpha_{IN}}{\alpha_{CN}}$ with $\alpha_{IN} = 1 - \alpha_{IT}$.

Investment expenditure on tradable goods $i_{T,t}$ is a CES basket of the home $i_{H,t}$ and foreign $i_{F,t}$ tradable goods:

$$i_{T,t}(i) = \left(\alpha_{IH}^{\frac{1}{\theta}} i_{H,t}^{\frac{\theta-1}{\theta}}(i) + (1-\alpha_{IH})^{\frac{1}{\theta}} i_{F,t}^{\frac{\theta-1}{\theta}}(i)\right)^{\frac{\theta}{\theta-1}} \tag{2.15}$$

where

$$i_{F,t}(i) = \left(\int_0^1 i_{F,t}^{\frac{\theta-1}{\theta}}(i,j)dj\right)^{\frac{\theta}{\theta-1}} \tag{2.16}$$

Firms allocate their investment demand by solving expenditure minimization problem (taking prices of goods as given).

Production in commodity sector is exogenously determined and does not incur any costs. Therefore, the profits of this sector are product of commodity endowment X_t and its price $p_{X,t}$:

$$\Pi_{X,t}(i) = p_{X,t}(i) X_t(i) \tag{2.17}$$

Total profits from the nontradable, tradable and commodity sectors are distributed across domestic households, so:

$$\Pi_t(i) = \Pi_{N,t}(i) + \Pi_{T,t}(i) + \Pi_{X,t}(i) \tag{2.18}$$

2.3.4 Market clearing conditions

All goods, factors and assets markets clear at any time and any contingency.
Markets of tradable and nontradable goods:

$$y_{N,t}(i) = c_{N,t}(i) + i_{N,t}(i), \forall i,\ t \tag{2.19}$$

$$y_{T,t}(i) = c_{H,t}(i) + \int_0^1 c_{F,t}(j,i)dj + i_{H,t}(i) + \int_0^1 i_{F,t}(j,i)dj, \forall i,\ t \tag{2.20}$$

Markets of commodity, capital and labor:

$$\int_0^1 X_t(i)di = \int_0^1 c_{X,t}(i)di + \int_0^1 x_{T,t}(i)di + \int_0^1 x_{N,t}(i)di, \forall t \quad (2.21)$$

$$i_t(i) = i^d_{T,t}(i) + i^d_{N,t}(i), \forall i,\ t \quad (2.22)$$

$$l_t(i) = l_{T,t}(i) + l_{N,t}(i), \forall i,\ t \quad (2.23)$$

Assets markets:

$$\int_0^1 e_t(s_t, j, i)a_t(s_t, i)di = 0, \forall j,\ t,\ s_t \quad (2.24)$$

2.3.5 Commodity and productivity shocks

To reduce this general model to the more tractable two-country (small commodity-exporting economy/the world economy) case I need to make several assumptions about the productivities and commodity endowments.

First, I assume, that among continuum of small open economies there is one economy of measure zero, hereafter called home economy. All other (foreign) economies are completely symmetric: they have the same productivities in nontradable and tradable sectors, $A^*_{N,t}$ and $A^*_{T,t}$, and commodity endowments, X^*_t, for any period and contingency. Home economy is assumed to be commodity abundant in the deterministic steady state, so that the following inequalities are satisfied:

$$\bar{A}^*_T/\bar{A}_T > \bar{A}^*_N/\bar{A}_N > \bar{X}^*/\bar{X} \quad (2.25)$$

where $\bar{A}_T$ ($\bar{A}^*_T$), $\bar{A}_N$ ($\bar{A}^*_N$) and $\bar{X}$ ($\bar{X}^*$) denote steady-state productivities of the tradable and nontradable firms and commodity endowments in the home (foreign) country respectively.

Second, I assume that commodity and productivity shocks in these two countries follow independent AR(1) processes:

$$\log A_{T,t} = (1-\rho_T)\log \bar{A}_T + \rho_T \log A_{T,t-1} + u_{T,t}$$
$$\log A_{N,t} = (1-\rho_N)\log \bar{A}_N + \rho_N \log A_{N,t-1} + u_{N,t}$$
$$\log X_t = (1-\rho_X)\log \bar{X} + \rho_X \log X_{t-1} + u_{X,t}$$

$$\log A^*_{T,t} = (1-\rho^*_T)\log \bar{A}^*_T + \rho^*_T \log A^*_{T,t-1} + u^*_{T,t}$$
$$\log A^*_{N,t} = (1-\rho^*_N)\log \bar{A}^*_N + \rho^*_N \log A^*_{N,t-1} + u^*_{N,t}$$
$$\log X^*_t = (1-\rho^*_X)\log \bar{X}^* + \rho^*_X \log X^*_{t-1} + u^*_{X,t}$$

where the innovations $u_{k,t}$ are independently (across countries and sectors) and normally distributed.

Since the home economy has measure zero it does not affect an equilibrium in the foreign economies. A symmetry across the last ones implies in turn a symmetry of their equilibrium allocations and prices.[10] So, I can treat a typical foreign economy as the world economy at whole.

To compute an equilibrium of this model I will proceed in two steps. Initially, I compute an equilibrium of the world economy (representative foreign economy). It provides us with the world prices of commodity $p^*_{X,t}$, foreign tradable good $p^*_{T,t}$ and Arrow-Debreu securities $q^*_{t,t+1}$ as well as with the foreign demands on tradable consumption $c^*_{T,t}$ and tradable investment $i^*_{T,t}$. These prices and allocations are contingent on foreign productivity and commodity shocks $A^*_{T,t}$, $A^*_{N,t}$ and X^*_t. An equilibrium in the home economy is computed in the second stage, taking the world demand and prices as given. All equilibrium conditions of the model are given in Appendix B.

2.3.6 Model with complete assets markets

Under the assumptions of complete markets and frictionless assets trade, the first-order optimal conditions for the home and foreign representative households imply that:

$$\frac{e_{t+1}}{e_t}\frac{U_c\left(c_{t+1},1-l_{t+1}\right)}{U_c\left(c_t,1-l_t\right)}=\frac{U_c\left(c^*_{t+1},1-l^*_{t+1}\right)}{U_c\left(c^*_t,1-l^*_t\right)} \tag{2.26}$$

Therefore,

$$e_tU_c\left(c_t,1-l_t\right)=\vartheta_0U_c\left(c^*_t,1-l^*_t\right) \tag{2.27}$$

where ϑ_0 is constant for all periods and contingencies and reflects an initial wealth position of the home economy comparing to the foreign one.

It means, that given the correction for wealth differences, a marginal rate of substitution between home and foreign consumption has to be equal to their relative price, i.e. the real exchange rate. In other words, other things being equal, consumption is higher in the country where its price, converted into a common currency, is lower.[11] It is in contrast to empirical evidence, which suggests that there are no any systematic comovement between relative consumption and real exchange rate. This collusion is well known

[10] In particular, symmetric equilibrium in the world economy implies that $c_{F,t}(i)=c_{F,t}(i,j)=c^*_{F,t}$, $i_{F,t}(i)=i_{F,t}(i,j)=i^*_{F,t}$, $p_{T,t}(i)=p_{H,t}(i)=p_{F,t}(i)=p^*_{T,t}$ and, consequently, $c_{T,t}(i)=c_{H,t}(i)+c_{F,t}(i)=c^*_{T,t}$ and $i_{T,t}(i)=i_{H,t}(i)+i_{F,t}(i)=i^*_{T,t}$ for all foreign economies i and j. So, in the equilibrium differentiated foreign tradable goods can be treated as one homogeneous foreign tradable good. Besides, equilibrium financial asset holdings of the foreign economy are null for any period and contingency: $a_t(i)=0$.

[11] Non-separability of consumption and leisure in utility implies that correlation between relative consumption and real exchange rate is not perfect in contrast to correlation between cross-country marginal rate of substitution and real exchange rate. Nevertheless, the simulation results show that this effect is negligible.

in the economic literature and is called a consumption-real exchange rate anomaly or a Backus-Smith puzzle (Backus and Smith, 1993).

It should be emphasized, that condition (2.27) does not imply in general a perfect international risk-sharing, understood as a lock-step comovement of consumption across countries in response to productivity and commodity shocks. As Brandt, Cochrane, and Santa-Clara (2006) stress, a risk sharing requires also frictionless goods markets. They argue:

> Suppose that Earth trades assets with Mars by radio, in complete and frictionless capital markets. If Mars enjoys a positive shock, Earth-based owners of Martian assets rejoice in anticipation of their payoffs. But trade with Mars is still impossible, so the real exchange rate between Mars and Earth must adjust exactly to offset any net payoff. In the end, Earth marginal utility growth must reflect Earth resources, and the same for Mars. Risk sharing is impossible. If the underlying shocks are uncorrelated, the exchange rate variance is the sum of the variances of Earth and Mars marginal utility growth, and I measure a zero risk sharing index despite perfect capital markets... At the other extreme, if there is costless trade between the two planets (teletransportation), and the real exchange rate is therefore constant, marginal utilities can move in lockstep. With constant exchange rates, I measure a perfect risk sharing index of one.

In my model there are nontradable goods. Besides, consumption of tradable goods, which are not perfect substitutes across countries, is home-biased. So, the productivity shocks in tradable and nontradable sectors cannot be perfectly insured and result in volatile real exchange rate. Non-separability of consumption and leisure in utility together with nontradable labor imply some degree of real exchange rate volatility too.

2.3.7 Model of financial autarky

In the model with complete markets, an international risk sharing is not too bad despite the presence of frictions in international trade. In other words, these frictions are not sufficient to induce an observed high volatility of the real exchange rate in commodity-exporting economies. International capital markets are prefect and provide enough insurance against productivity and commodity shocks.

Now, in contrast, I assume that international financial markets disappeared and the home economy has no access to international borrowing and saving, but is allowed to trade intratemporally. This is the case of financial autarky, which, to some extent, is opposite to the model with complete markets.

The home representative household in this model maximizes its expected life-time utility subject to a new sequence of budget constraints:

$$c_t \le w_t l_t + \Pi_t \tag{2.28}$$

where c_t is a composite consumption good, l_t denotes hours worked, w_t is a real wage and Π_t denotes profits from the home firms and endowment.

The foreign representative household's problem, problems of the firms and market clearing conditions (except of the absent assets markets) are analogous to the previous case. As in the model with complete markets, the world prices are completely determined in the equilibrium for the world economy. The equilibrium conditions for this model are reported in Appendix B.

The law of one price for financial assets and consequently condition (2.27) are not satisfied in the model of financial autarky. Instead, an equilibrium in the home economy is determined by the balanced trade condition:

$$tb_t = p_{H,t}(c^*_{H,t} + i^*_{H,t}) + p_{X,t}(X - c_{X,t} - x_{T,t} - x_{N,t}) - p_{F,t}(c_{F,t} + i_{F,t}) = 0 \tag{2.29}$$

where $p_{H,t}(c^*_{H,t} + i^*_{H,t})$ and $p_{X,t}(X - c_{X,t} - x_{T,t} - x_{N,t})$ are exports respectively of home tradable goods and commodity, whereas $p_{F,t}(c_{F,t} + i_{F,t})$ is import of foreign tradables.

To compare this model with the complete markets case it would be useful to compute the time and state-varying variable ϑ_t reflecting the wedge between the cross-country marginal rate of substitution of consumption and the real exchange rate:

$$e_t U_c\left(c_t, 1 - l_t\right) = \vartheta_t U_c\left(c^*_t, 1 - l^*_t\right) \tag{2.30}$$

This wedge induces an additional volatility in the real exchange rate and solves the Backus-Smith puzzle, breaking the link between relative consumption and real exchange rate. Nevertheless, financial autarky is a too restrictive assumption. So, it would be interesting to consider an intermediate case, where the home country can borrow and save abroad but there are frictions in financial assets trade.

2.3.8 Model with portfolio adjustment costs

Now I assume, that when adjusting the portfolio of international assets the agents bear transaction costs. Home representative household in this model maximizes expected lifetime utility subject to a modified sequence of budget constraints:

$$\begin{aligned} &c_t + \int_{s_{t+1}} q_{t,t+1}(s_{t+1}, i) a_{t+1}(s_{t+1}, i) ds_{t+1} + \\ &+ p_{N,t} \Psi_a \left(\int_{s_{t+1}} q_{t,t+1}(s_{t+1}, i) a_{t+1}(s_{t+1}, i) ds_{t+1} - a_t \right) \le a_t + w_t l_t + \Pi_t \end{aligned} \tag{2.31}$$

where c_t is a composite consumption good, l_t denotes hours worked, w_t is a real wage, a_{t+1} denotes portfolio of Arrow-Debreu securities priced at $q_{t,t+1}$, $\Psi_a(\cdot)$ are portfolio adjustment costs and Π_t are profits. I assume that all portfolio adjustment costs are paid in nontradable goods and $\Psi_a(\cdot)$ is a convex function satisfying the following properties: $\Psi_a(z) \geq 0$ and $\Psi_a(z) = 0$ if and only if $z = 0$, $z\Psi_a'(z) \geq 0$ and $\Psi_a''(z) > 0$.[12]

The foreign representative household's problem, problems for the firms and market clearing conditions are the same as in the complete markets model.[13]

The first order intertemporal optimal condition for the representative household is given by:

$$q_{t,t+1} = \beta \frac{U_c\left(c_{t+1}, 1 - l_{t+1}\right)}{U_c\left(c_t, 1 - l_t\right)} \frac{1 + p_{N,t+1}\Psi_{a,t+1}'}{1 + p_{N,t}\Psi_{a,t}'} \tag{2.32}$$

where $\Psi_{a,t}' = \Psi_a'\left(tb_t\right)$.

This condition implies that:

$$e_t U_c\left(c_t, 1 - l_t\right) = \vartheta_t U_c\left(c_t^*, 1 - l_t^*\right) \tag{2.33}$$

where

$$\vartheta_t = \frac{\vartheta_0}{1 + p_{N,t}\Psi_a'(tb_t)} \tag{2.34}$$

So, in this model there is a wedge between cross-country marginal rate of substitution and the real exchange rate. This wedge implies a negative correlation between the real exchange rate and the world commodity prices. Indeed, negative commodity shock in the foreign economy results in commodity price growth and trade balance surplus. Since ϑ_t is a decreasing function of the trade balance, the real exchange rate have to decrease (appreciate).

Besides, this model generates an additional volatility in the real exchange rate and solves the Backus-Smith puzzle. But, in contrast to the financial autarky, it allows international borrowings and savings.

2.4 Calibration

The model was calibrated to the Canadian economy, whereas the parameters of the world economy were approximated using US data. The calibrated parameters are summarized in Table B.2.

[12] These convex portfolio adjustment costs are somewhat ad hoc. However, the main aim of this chapter is not to explain a source of financial frictions, but to illustrate the effects of these frictions on business cycles in a small commodity-exporting economy.

[13] Given that portfolio adjustment costs are paid in home nontradable good, the market clearing condition for this good is now: $y_{N,t} = c_{N,t} + i_{N,t} + \Psi_a\left(\int_{s_{t+1}} q_{t,t+1}(s_{t+1}, i)a_{t+1}(s_{t+1}, i)ds_{t+1} - a_t\right)$.

Table B.3 presents the breakdown of industries into commodity, tradable and nontradable sectors according to the International Standard Industrial Classification (ISIC, Rev. 3). The commodity sector includes agriculture, mining and selected manufacturing industries producing semi-processed raw materials (wood and pulp, metals, chemicals, petroleum and coal products, etc.). The tradable sector consists of the rest of manufacturing (food and tobacco, textile, machinery and equipment manufacturing, etc.) and internationally traded services (transport, financial intermediation, computer and other business services). The nontradable sector includes the rest of services, public utilities and construction.

2.4.1 Preferences and technology

The following functional form for the utility function is assumed in this chapter:

$$U(c, 1-l) = \frac{\left(c^{\gamma}(1-l)^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}$$

This functional form implies that consumption and leisure are non-separable in utility. The discount factor β is set to 0.99 to match 4% annual real rate in steady state. The risk aversion parameter σ is equal to 2. The labor share γ is set to 0.38, so the fraction of working time in steady state is 30%.

The elasticity of substitution in consumption between commodity, tradable and nontradable goods ϵ is set to 0.74 following Mendoza (1995). I assume that elasticity of substitution between home and foreign tradable goods θ is equal to 1.5 as in Backus, Kehoe, and Kydland (1992). The shares of tradable ($a_{CT} = 0.23$) and nontradable ($a_{CN} = 0.73$) goods in consumption basket were computed using input-output data for Canada.[14] The weight of home tradable good in tradable consumption a_{CH} is set to 0.68. The corresponding shares for investment are $a_{IT} = 0.38$ and $a_{IH} = 0.31$. So, the weight of tradable goods in investment is higher than in consumption. Besides, consumption of tradables in Canada is home-biased, whereas investment expenditure on tradable goods goes predominantly to import.

The shares of capital in the value added, b_{TK} and b_{NK}, are computed using input-output data for Canada, found to be approximately the same across sectors and equal to 0.34. The weights of commodity input in total costs for tradable ϕ_T and nontradable ϕ_N sectors are set to 20% and 10% respectively. So, the tradable sector uses commodity more intensively than the nontradable one, what makes it more vulnerable to the commodity price hikes. The elasticity of substitution between value added and commodity input ξ is set to 0.69 for both sectors. That is in the line with the estimate of Rotemberg and Woodford (1996). I assume also that the capital stocks in both sectors depreciate at the

[14]OECD Input-Output Database, 2006 edition.

same rate of 2.5% per quarter.

The steady-state productivity levels in the foreign tradable A_T^* and nontradable A_N^* sectors were computed, assuming that in the steady state all prices of foreign goods (in terms of the foreign consumption) are equal to 1 and normalizing the steady-state foreign commodity endowment X^* to 1. Both values are found to be equal to 3.13. To compute the productivity levels in tradable A_T and nontradable A_N sectors in the home country I use the estimates of multi-factor productivity gap between US and Canada for different industries, reported by Rao, Tang, and Wang (2004). According to these estimates the productivity levels in Canada constitute 79% and 92% of those in US for tradable and nontradable sectors respectively. Implied values of A_T and A_N are equal to 2.47 and 2.88. It is assumed also that the home economy is commodity abundant, so in the steady state $X = 1.41$.

Finally, we need to calibrate the stochastic processes describing productivity and commodity endowments shocks. The serial correlation coefficients are assumed to be symmetric across sectors and countries and equal to $\rho = 0.8$. The standard deviations of innovations in tradable and nontradable sectors are set to satisfy proportion two to one in both countries. The shocks to commodity endowments are assumed to be twice more volatile than productivity shocks in tradable sector for the home economy and three times more volatile for the foreign economy. These proportions correspond roughly to those computed from the OECD data on labor productivity (see Table C.1 in Chapter 3).[15]

2.4.2 Capital and portfolio adjustment costs

The capital adjustment costs are symmetric across sectors and countries. The following functional form is assumed in this chapter: $\Psi_k(z) = \psi_0 + \psi_1 z^{\psi_2}$. The parameters are set to guarantee, that in the steady-state equilibrium $\Psi_k(\delta) = \delta$, $\Psi_k'(\delta) = 1$ and $\Psi_k''(\delta) = d < 0$. The value of d is chosen so as to ensure that a volatility of investment is three times higher than that of GDP.

The portfolio adjustment costs function is $\Psi_a(z) = \psi z^2$. The parameter ψ is set so to guarantee that a standard deviation of trade balance to GDP ratio is equal to 0.9, as in the data for Canada.

2.4.3 Algorithm

The equilibrium conditions of the model are log-linearized around the deterministic steady state. A corresponding system of linear expectational difference equations is solved by generalized Schur decomposition (QZ) algorithm (see Klein, 2000; Sims, 2002) realized in

[15]Notice that (HP-filtered) labor productivity in the Canada's commodity sector was less volatile in 1980-2008 comparing to the OECD average and United States.

Dynare[16] package.

2.5 Results

This section reports the steady-state solution and simulation results for the different variants of the model of a small commodity-exporting economy.

2.5.1 Deterministic steady-state equilibrium

Given the cross-country asymmetries in the model, it would be interesting to consider its deterministic steady-state equilibrium. It is assumed that both economies have balanced trade in the steady state, so the corresponding equilibria are the same for all variants of the model. The steady-state solution is presented in Table B.4. Several observations are worth noting.

First, international trade flows fit well with the predictions of the comparative advantage theory. The home economy exports primary commodities whereas its import of foreign tradable goods exceeds the export of home tradables. Moreover, the relative price of domestic tradables to commodity in the home country is higher than abroad.

Second, production in the home economy is skewed to the commodity and nontradable sectors. Besides, home nontradable firms use relatively more labor, capital and raw materials comparing to tradable firms. The relative resource abundance of the home country implies also that both its non-commodity sectors use primary commodities more intensively than their foreign counterparts.

And finally, the steady-state real exchange rate in the home economy is less than unity (it is equal to 0.78), so the international price level in this economy is higher than abroad.[17] That means that prices of nontradable and domestic tradable goods are higher in the home country when expressed in the same currency.

It should be mentioned that this last result is far from general when applying to commodity-exporting economies. Figure B.3 illustrates dynamics of the international price levels in the four developed resource rich countries: Australia, Canada, Norway and New Zealand. Though the prices in Norway are significantly higher than in the United States (the average for the period from 1970 to 2008 is close to 130% of the U.S. level), in Canada and Autralia they are close to parity (the averages are 100% and 97% of the U.S. level respectively) whereas in New Zealand the international price level is lower than in the United States (86% of the U.S. level). Besides, it is well-known that all developing countries have low international price levels despite the fact that many of

[16] http://www.cepremap.cnrs.fr/dynare/

[17] Notice, that the real exchange rate is defined in this chapter as a price of foreign consumption in terms of home consumption. So, the international price level is an inverse of the real exchange rate.

them are commodity-exporting countries.[18]

It is not so difficult to explain these discrepancies. According to the well-known Harrod-Balassa-Samuelson hypothesis, the countries with a higher relative productivity in tradable sector compared to the nontradable one usually have higher price levels. In my model, the tradable sector consists of the primary commodity and non-commodity tradable goods industries. Though the commodity-exporting countries are very productive in commodity sector they may be significantly less productive in the rest of the tradable sector. If the second factor dominates the first one, the international price levels in these countries will be lower than abroad.

Besides, an important role in my model is played by the degree of substitutability in consumption between home and foreign non-commodity tradable goods. In the case of low elasticity of substitution, the prices of these goods may significantly deviate from the law of one price without any strong effects on demand.[19] Therefore, the relatively higher prices of the home tradable goods may compensate for relatively low productivity in tradable sector dumping Harrod-Balassa-Samuelson effect. In contrast, if the home and foreign tradable goods were perfect substitutes, the law of one price between these goods would be satisfied precisely and international price level in the home country would be lower. So, for example, increasing the elasticity of substitution θ from 1.5 to 15 results in decreasing the steady-state international price level in the home country from 128% (inverse of 0.78) to 100% of the foreign level (which is close to Canada's average).[20]

2.5.2 Business cycles statistics

This section presents the second moments generated by different variants of the model of a small commodity-exporting economy and compares these moments with those found in the data. To compute these statistics I simulated the model 100 times. After that I took logs of all variables[21] and detrended them with HP-filter. The adjusted series were used for computation of standard deviations and correlations between variables. I calculated means and standard errors of these statistics along simulations. The quarterly series for Canada in 1985-2008 were used to compute the second moments of the data.[22] Table B.5 summarizes the basic results.

The simulated standard deviations conform well with the data. The volatility of GDP in home country varies between 1.55 and 1.71 across models, that is close to the observed

[18]According to the World bank's International Comparison Program (ICP) in 2005, even the rich OPEC countries have lower than the United States price levels: 73% in Kuwait, 75% in Qatar and 64% in Saudi Arabia.

[19]Recall that the law of one price is one of the assumptions in the Harrod-Balassa-Samuelson theory.

[20]Notice, that these long-run deviations from PPP may be explained also by cross-country differences in consumption composition as well as by differences in taxation and trade policy.

[21]except of the net export, which is reported as a share of GDP.

[22]I used data of the OECD Economic Outlook provided by EcoWin database.

value of 1.78 in Canada.[23] The highest volatility of GDP is generated by the model of financial autarky. Standard deviation is equal to 1.71 in this model, comparing with 1.55 in the complete markets case. It can be explained by the asymmetric effect of the world commodity price changes on commodity and non-commodity sectors of the home economy under the complete markets assumption. In this model, the negative effect of commodity shock on the foreign economy is transmitted to the home economy, where output of tradable and non-tradable goods decreases. At the same time, the value of commodity endowment in the home country increases as a result of higher commodity price. In contrast, in the model of financial autarky international risk sharing does not work, so the first effect is negligible and increase of GDP in commodity sector is not compensated by decrease of production in other sectors. As a result, home GDP is more volatile in this model.

Furthermore, consumption and employment are less volatile whereas investment is more volatile than GDP in all variants of the model. That conforms well to standard results in the business cycles literature. In the model with portfolio adjustment costs standard deviations of consumption and investment are close to data, 0.99 and 4.13 versus 0.91 and 4.12 respectively.

The calibrated stochastic process for commodity endowment in the foreign economy generates the volatility of the real world commodity price equal to 9.51, which is close to 9.26 in the data. The resultant standard deviation of trade balance in the complete markets model is too high, 1.90 vs. 0.91 in data, whereas the volatility of the real exchange rate is too small, 1.39 against 3.47. That indicates an excessive international risk sharing implied by the model with complete markets. The model of financial autarky represents an opposite extreme with the standard deviations of trade balance and real exchange rate equal to 0 and 5.56 respectively. By calibrating the portfolio adjustment parameter ψ I set the volatility of trade balance to 0.90 in the intermediate model. Induced volatility of the real exchange rate is equal to 3.18, what is close to the observable value of 3.47.

The correlations of GDP, consumption, investment and employment between foreign and home economies are positive in the data. Besides, consumption and employment are more correlated across countries than GDP and investment, reflecting a high degree of international risk sharing. The complete markets model and the model with portfolio adjustment costs succeed in general to replicate these facts. The only problem is related to the correlation between foreign and home GDP, which is close to zero in the model but positive in the data. In the first chapter to this thesis I show that global demand shocks may account for significant part of this cross-country correlation in GDP. In this chapter, however, I abstract from the demand shocks. Besides, the productivity and commodity shocks in home and foreign economies are assumed to be independent. That implies a

[23]Notice, that real GDP is computed in this chapter by dividing the nominal GDP by consumption price deflator.

low correlation between home and foreign GDP.

Another discrepancy between data and model is a low simulated correlation between the real commodity price and home GDP. The model of financial autarky is the closest to the data in this respect. The corresponding correlation is equal to 0.17 against 0.58 in the data. There are two reasons for this discrepancy. On the one hand, this problem is related to the delayed effect of commodity prices on the global economic activity. It is known from the Chapter 1 that commodity-specific shocks affect the global output (and consequently the home GDP) only with one year delay. The model, in contrast, generates an immediate negative effect of the foreign commodity endowment shock to foreign GDP, which is transmitted through international risk sharing to the home economy. As a result, this negative effect dominates a positive effect of commodity prices on the value of home commodity output in the models with high degree of international risk sharing. On the other hand, a positive correlation of the real GDP and real commodity prices in the data may be explained partially by the fact, that global demand shocks have strong positive effect both on the real commodity prices as well as on the economic activity in home country.

The models with complete markets and with portfolio adjustment costs illustrate clearly the external balances effect. Trade balance in these models is positively correlated with the real commodity price. Correlation coefficient is 0.84 in both models. That conforms well with data for Canada, where the corresponding correlation is positive and equal to 0.43.

The most interesting simulation results are related to correlation between real commodity price and real exchange rate on the one hand and to correlation between real exchange rate and relative consumption on the other. The model with complete markets fails to generate a significant commodity currency effect. Correlation of the real exchange rate with the real commodity price is equal to -0.07 in this model versus -0.43 in data. It is also prone to the Backus-Smith anomaly, given the unitary correlation between the real exchange rate and relative consumption. The model of financial autarky is free from these problems. Commodity price-real exchange rate correlation for this model is equal to -0.81 and relative consumption is negatively correlated with its relative price (-0.45 vs. -0.31 in the data). The model with portfolio adjustment costs also provides reasonable results: corresponding correlations are -0.76 and 0.04.

Another important result of the model is a manifestation of the Dutch disease. Volatility of output in the tradable sector is higher for financial autarky comparing with the complete markets model (4.4 versus 3.47) whereas output in nontradable sector is less volatile (1.54 for financial autarky and 1.91 for complete markets). Besides, output of the tradable sector in the financial autarky case is more correlated with the real commodity prices and real exchange rate.

Tables B.6-B.8 report the business cycles statistics generated by only one type of shock, respectively by shocks in the foreign commodity, tradable and nontradable sectors. The foreign commodity shocks induce the highest volatility of the real commodity price, 9.39 versus 0.93 for tradable and 1.44 for nontradable shocks. They also imply the highest standard deviation of trade balance.

The complete markets model fails to generate significant volatility of the real exchange rate after commodity shocks, but for the nontradable and tradable shocks corresponding standard deviations are quite large, 0.94 and 0.25 respectively. As it was explained earlier, this volatility is related to the frictions in international trade, presence of nontradable goods and home bias in consumption of tradable goods. Nevertheless, this induced volatility of the real exchange rate is still much lower than volatility implied by the frictions in assets trade.

2.5.3 Impulse responses

To provide some intuition about the mechanics of business cycles in commodity-exporting country I report here the dynamic responses of selected macroeconomic variables to foreign commodity and productivity shocks. Further to the three aforementioned models I present also the results for the incomplete markets case, i.e. the model where only non-risky bond is traded. Since the impulse responses for this model are very close to those of the model with complete markets, I will not discuss them hereinafter.

Figures B.4-B.8 plot the impulse responses to a negative commodity shock in the foreign economy. This shock results in a significant increase of the real commodity price, whereas its effect on the foreign economy is unambiguously negative. All foreign allocation variables, such as output, consumption, employment, investment, capital, etc., decrease. Foreign wages and capital returns fall too, whereas foreign real rate of interest increases after the negative transitory commodity shock. Since the tradable sector uses primary commodities more intensively, an effect of the commodity shock is more pronounced for it. Indeed, the price ratio between foreign nontradable and tradable goods decreases. As a result, consumption and investment demand on foreign tradable goods reduces respectively by 1% and 5%, comparing to 0.5% and 4% for nontradables. Production of tradables declines by 2% vs. 1% in the nontradable sector.

The effect of the negative foreign commodity shock on the home economy is ambiguous and depends on the model. In the model with complete markets this shock is almost perfectly insured[24], so all home variables, except of GDP, behave similarly to the foreign ones. In response to the higher world commodity price home economy increases commodity export, decreasing its supply for own purposes. That continues until the relative prices, as well as the marginal utilities of consumption, in the home and foreign economies will not be equalized. As a result, trade balance expands, but the real exchange rate does

[24]Non-separability of consumption and leisure in the utility prevents perfect insurance.

not change significantly. Dynamics of GDP in the home country depend on two opposite effects. Output in the tradable and nontradable sectors falls in response to higher commodity price, but the value of commodity endowment in terms of consumption increases. Hence, total GDP may increase or decrease depending on which effect dominates. Given our benchmark parameters, GDP in the home economy falls under complete markets, but not so significantly as home consumption and foreign GDP.

In the model of financial autarky the foreign commodity shock has more complicated effect on the home economy. On the one hand, higher commodity price negatively affects the home economy, increasing costs of production. This result is similar to the one described in the complete markets case. On the other hand, there is a positive spending effect due to the improved terms of trade and the absence of cross-country insurance. The overall effect may depend on the parameters of the model, so it is easier to describe the impulse responses of the model of financial autarky with a reference to those in the complete markets case.

The rising commodity prices tend to increase trade balance at home. But under the assumption of missing assets markets it is not possible. The real exchange rate has to appreciate to equalize export and import. That means that prices of home tradable goods increase comparing to the prices of foreign tradables. As a result, foreign consumption and investment demand on home tradable goods falls and home demand on foreign tradable goods rises, so the trade balance do not change. According to Figure B.5, the corresponding initial appreciation of the real exchange rate is equal to 4%.

In contrast to the complete markets model, the price ratio between nontradable and tradable goods increases, shifting the consumption to tradable goods. That increase falls mainly on the relatively cheap foreign tradables, whereas the consumption demand on home tradables shrinks. Nontradable consumption decreases under our benchmark calibration, but not so strongly as in the complete markets model, reflecting the spending effect.[25]

The model of financial autarky manifests also the investment effect. This effect is twofold. First, home tradable and nontradable firms increase their investment demand substituting expensive labor for cheap capital. Second, since the share of tradable goods in the basket of aggregate investment is higher than for aggregate consumption, the lower relative price of tradables results in lower relative price of investment. The home firms expect that after an initial fall the investment price will rise to its steady-state level. That increases the returns on investment in new capital in the tradable and nontradable sectors. In other words, investment is too cheap today comparing to tomorrow, so it is profitable to install new capital. Therefore, capital stock in the both sectors will rise until the positive effect of low investment prices will not be compensated by the diminishing

[25] The higher steady-state commodity endowment in the home economy may lead even to an initial growth of the nontradable consumption.

marginal return to capital. Besides, investment demand on the tradable goods increases more strongly than investment demand on nontradables, reflecting their low relative price.

The impulse responses in the model of financial autarky illustrate also the effect of Dutch disease. Given the declining price competitiveness in the home tradable sector comparing to the foreign one, its output decreases more significantly than under the complete markets assumption.[26] At the same time, output in the nontradable sector slightly grows. Labor shifts from the home tradable sector to production of nontradables. Meanwhile, home tradable firms substitute expensive labor for cheap capital, increasing their capital stock despite the reduction in output. Total GDP in the home economy increases as a result of higher value of commodity endowment and the higher production of nontradable goods.

The model with portfolio adjustment costs generate intermediate results. On the one hand, this model allows some degree of international risk sharing despite the frictions in assets trade. So, trade balance in the home country will rise in response to the negative foreign commodity shock, but not so strongly as in the complete markets case. On the other hand, since the home savings abroad are not enough to fully insure against the commodity shocks, this model will generate an appreciation of the real exchange rate and a positive spending effect, as in the case of financial autarky. Its overall effect depends on how high the portfolio adjustment costs are and may vary between these two extremes.

Though the main contribution to volatility in the world commodity prices is provided by the foreign commodity endowment shocks, the productivity shocks in the foreign tradable and nontradable sectors also affect commodity prices. Therefore, it would be interesting to consider the dynamic responses generated by these shocks.

Figure B.9 plots the impulse responses to the positive productivity shock in the foreign nontradable sector. An one percent increase in the productivity results in approximately the same increase in the real commodity price. Consumption and investment in the foreign economy rise due to this positive shock, though demand shifts to the cheaper nontradable goods. Production of the foreign tradables also increases, as this sector starts to use more labor, capital and commodity input. As a result, total foreign output grows.

Since the foreign nontradable goods cannot be consumed or invested in the home economy, the productivity shocks in the foreign nontradable sector are not insurable, even in the complete markets model. Home households are not able to increase their consumption as the foreign ones and the real exchange rate has to appreciate.[27] Besides, the relative price of primary commodities to foreign tradable goods increases, so the terms of trade in the home country improves and trade balance expands. Appreciation of the real exchange rate mitigates this terms-of-trade effect but fails to counteract it.

[26] So, the output volatility in the home tradable sector rises comparing to the foreign economy, making it more vulnerable to the world commodity price shocks.

[27] Recall, the story of Brandt et al. (2006) about the trade between the Earth and Mars.

In the model of financial autarky the real exchange rate appreciates even more to balance the trade between home and foreign countries. This model manifests a spending effect similar to that described earlier for commodity shocks. As a result, home output and consumption increases relative to complete markets benchmark. The model with portfolio adjustment costs again provides intermediate results.

Figure B.10 summarizes the effect of the positive productivity shock in the foreign tradable sector. Though the productivity in the tradable sector is more volatile than in the nontradable one, the effect on the real commodity price is very weak. The foreign nontradable sector absorbs commodity input released from the more productive tradable sector but uses it less intensively, so the commodity price increase is not too strong. Consumption and investment in the foreign economy rise due to positive shock, but demand shifts to the tradable goods. Production of the foreign tradable and nontradable goods as well as total foreign output increase.

In contrast to the nontradable productivity shock, the home economy can reap from the positive productivity shocks in the foreign tradable sector. In the complete markets model, the home households and firms increase their import of cheap foreign tradable goods, simultaneously augmenting their borrowing from abroad (given a very low foreign real rate of interest). As a result, home trade balance falls despite an increase in the terms of trade. However, since the foreign and home tradable goods are not perfect substitutes and there is home bias in the consumption of tradables, the home households cannot increase their consumption as much as the foreign ones. So, the real exchange rate has to appreciate a little.

In the model of financial autarky balancing the trade means decreasing the import of foreign tradable goods. So, the real exchange rate appreciates less than in the complete markets model. Nevertheless, this effect is negligible and does not change significantly the home consumption and output.

2.5.4 Sensitivity analysis

This section presents a sensitivity analysis of the model of a small commodity-exporting economy with respect to its three key parameters: i) size of the home commodity sector, X, ii) elasticity of substitution between home and foreign tradable goods, θ, and iii) volatility of the commodity shocks in the foreign country, $std(u_X^*)$. Table B.9 summarizes the results for the model with portfolio adjustment costs.

In the first sensitivity experiment I consider the effect of changing the size of the home commodity sector on the business cycles properties of the model. The model was simulated under three scenarios: the benchmark scenario with $X = 1.41$, a small commodity sector with $X = 1$[28] and a large commodity sector $X = 3$. Increasing X results in higher

[28]Though the size of the commodity sector under this scenario is the same in both the home and foreign

volatility of home GDP and investment, whereas these variables become more correlated with the world commodity prices and less correlated with their foreign counterparts. Standard deviation of the real exchange rate increases too despite slightly rising volatility of the trade balance. Negative correlation between the real exchange rate and commodity prices becomes more apparent, as well as negative relation of the real exchange rate with the cross-country consumption differential.

The second experiment deals with the changes in the elasticity of substitution between home and foreign tradable goods. Together with the benchmark value of $\theta = 1.5$, I consider here two other alternatives: $\theta = 0.74$ and $\theta = 15$. As in the previous scenario, an increase in the elasticity of substitution between home and foreign tradable goods leads to rising volatility of home GDP and investment, whereas these variables become more correlated with the world commodity prices and less correlated with the foreign GDP and investment. It may be explained by the fact, that under very high substitutability of home and foreign tradable goods, small changes in the real exchange rate result in significant changes of the demand on home tradable goods, as well as in large reallocations of resources between home tradable and nontradable sectors. In the extreme case of perfect substitutability, home output of the tradable goods may be completely ousted by the foreign import. So, the Dutch disease becomes more acute and the home economy is more sensitive to the world commodity price changes.

Finally, I provide a sensitivity analysis of the changes in volatility of the foreign commodity shocks. In the benchmark calibration exercise, the foreign commodity endowment shocks have standard deviation equal to 6.9. That is one and half times higher than in the home economy. I also consider two alternative scenarios. The first one assumes the same volatility in the commodity sector for both countries, $std(u_X^*) = 4.6$. In the second scenario, the foreign commodity endowment is twice more volatile than in the home country. The simulations show, that increasing the volatility of the foreign commodity endowment leads to a significant growth of the commodity price volatility. And as a result, the home trade balance and real exchange rate become more correlated with the real commodity price, whereas their standard deviations increase. Since the model with portfolio adjustment costs allows some degree of cross-country risk sharing, the rising volatility of the foreign consumption and employment is transmitted to the rising volatility of these variables in the home country. Besides, consumption and employment become more correlated across countries.

economies, the foreign economy is more productive in the tradable sector. Therefore, the home country has a comparative advantage in production of the primary commodities and is a net commodity-exporter in the steady-state equilibrium.

2.6 Conclusions

In this chapter I presented the model successfully generating the main stylized facts about business cycles in a small commodity-exporting economy. These facts include procyclical effects of the world commodity price changes on investment and trade balance, volatile and negatively correlated with the real commodity price real exchange rate, absence of correlation between the real exchange rate and relative consumption and Dutch disease. This model demonstrates a high degree of international risk sharing, reflected in the positive cross-country correlations of consumption and employment. Nevertheless, it is free from anomalies, related to perfect functioning of the international assets markets, such as Backus-Smith puzzle and a low volatility of the real exchange rate.

This analysis has several implications. First, to ease the problems related to high volatility of the real exchange rate and Dutch disease, the financial markets have to function well. Since in many countries windfall revenues from commodity export are heavily taxed, stabilization funds are crucial for smoothing the government spending over the business cycles. The importance of this mechanism rises for the countries with a very large commodity sector. Second, the burden of Dutch disease for the home tradable sector is not too strong if the home and foreign tradable goods are weak substitutes. In this case, the fluctuations in prices of the home tradable goods do not affect significantly demand on them and do not result in large cross-sectoral reallocations of labor and capital.

Appendix B

Appendices to Chapter 2

B.1 The model with complete markets

B.1.1 Foreign economy

An equilibrium of the world economy (typical foreign economy) is given here. This equilibrium is not affected by the allocations and prices in the home economy since the latter has zero measure.

The first-order equilibrium conditions for the representative household's problem in the foreign economy are:

$$q^*_{t,t+1}U_c\left(c^*_t,1-l^*_t\right)=\beta U_c\left(c^*_{t+1},1-l^*_{t+1}\right) \tag{B.1.1}$$
$$w^*_tU_c\left(c^*_t,1-l^*_t\right)=U_l\left(c^*_t,1-l^*_t\right) \tag{B.1.2}$$

Foreign demand on aggregate consumption good and its components:

$$c^*_t=\left(\alpha_{CT}^{\frac{1}{\epsilon}}c^{*\,\frac{\epsilon-1}{\epsilon}}_{T,t}+\alpha_{CN}^{\frac{1}{\epsilon}}c^{*\,\frac{\epsilon-1}{\epsilon}}_{N,t}+(1-\alpha_{CT}-\alpha_{CN})^{\frac{1}{\epsilon}}c^{*\,\frac{\epsilon-1}{\epsilon}}_{X,t}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.1.3}$$
$$c^*_{T,t}=\alpha_{CT}p^{*\,-\epsilon}_{T,t}c^*_t,\;\; c^*_{N,t}=\alpha_{CN}p^{*\,-\epsilon}_{N,t}c^*_t,\;\; c^*_{X,t}=(1-\alpha_{CT}-\alpha_{CN})p^{*\,-\epsilon}_{X,t}c^*_t \tag{B.1.4}$$

Value added and total output of the foreign tradable and nontradable firms and real GDP in terms of the foreign consumption good:

$$v^*_{N,t}=A^*_{N,t}k^{*\beta_{NK}}_{N,t}l^{*1-\beta_{NK}}_{N,t},\;\; v^*_{T,t}=A^*_{T,t}k^{*\beta_{TK}}_{T,t}l^{*1-\beta_{TK}}_{T,t} \tag{B.1.5}$$
$$y^*_{N,t}=\left((1-\phi_N)^{\frac{1}{\xi}}v^{*\,\frac{\xi-1}{\xi}}_{N,t}+\phi_N^{\frac{1}{\xi}}x^{*\,\frac{\xi-1}{\xi}}_{N,t}\right)^{\frac{\xi}{\xi-1}} \tag{B.1.6}$$
$$y^*_{T,t}=\left((1-\phi_T)^{\frac{1}{\xi}}v^{*\,\frac{\xi-1}{\xi}}_{T,t}+\phi_T^{\frac{1}{\xi}}x^{*\,\frac{\xi-1}{\xi}}_{T,t}\right)^{\frac{\xi}{\xi-1}} \tag{B.1.7}$$
$$y^*_t=p^*_{T,t}y^*_{T,t}+p^*_{N,t}y^*_{N,t}+p^*_{X,t}(X^*_t-x^*_{T,t}-x^*_{N,t}) \tag{B.1.8}$$

Capital in the foreign economy:

$$k^*_{N,t+1}=(1-\delta)k^*_{N,t}+k^*_{N,t}\Psi_k\left(\frac{i^{d*}_{N,t}}{k^*_{N,t}}\right) \tag{B.1.9}$$
$$k^*_{T,t+1}=(1-\delta)k^*_{T,t}+k^*_{T,t}\Psi_k\left(\frac{i^{d*}_{T,t}}{k^*_{T,t}}\right) \tag{B.1.10}$$

The first-order intertemporal conditions for the profit maximization problems of the foreign nontradable and tradable firms:

$$\beta E_t \frac{U_c\left(c^*_{t+1}, 1-l^*_{t+1}\right)}{U_c\left(c^*_t, 1-l^*_t\right)} \frac{p^*_{KN,t+1}}{p^*_{KN,t}} \left(1 + r^*_{N,t+1} - \delta + \Lambda^*_{N,t+1}\right) = 1 \tag{B.1.11}$$

$$\beta E_t \frac{U_c\left(c^*_{t+1}, 1-l^*_{t+1}\right)}{U_c\left(c^*_t, 1-l^*_t\right)} \frac{p^*_{KT,t+1}}{p^*_{KT,t}} \left(1 + r^*_{T,t+1} - \delta + \Lambda^*_{T,t+1}\right) = 1 \tag{B.1.12}$$

$$p^*_{KN,t} = p^*_{I,t} / \Psi'_k \left(\frac{i^{d*}_{N,t}}{k^*_{N,t}}\right), \quad p^*_{KT,t} = p^*_{I,t} / \Psi'_k \left(\frac{i^{d*}_{T,t}}{k^*_{T,t}}\right) \tag{B.1.13}$$

$$\Lambda^*_{N,t} = \Psi_k \left(\frac{i^{d*}_{N,t}}{k^*_{N,t}}\right) - \frac{i^{d*}_{N,t}}{k^*_{N,t}} \Psi'_k \left(\frac{i^{d*}_{N,t}}{k^*_{N,t}}\right), \quad \Lambda^*_{T,t} = \Psi_k \left(\frac{i^{d*}_{T,t}}{k^*_{T,t}}\right) - \frac{i^{d*}_{T,t}}{k^*_{T,t}} \Psi'_k \left(\frac{i^{d*}_{T,t}}{k^*_{T,t}}\right) \tag{B.1.14}$$

Capital, labor and commodity demand of the foreign firms:

$$k^*_{N,t} = \beta_{NK} \left(\frac{r^*_{N,t} p^*_{KN,t}}{p^*_{VN,t}}\right)^{-1} v^*_{N,t}, \quad k^*_{T,t} = \beta_{TK} \left(\frac{r^*_{T,t} p^*_{KT,t}}{p^*_{VT,t}}\right)^{-1} v^*_{T,t} \tag{B.1.15}$$

$$l^*_{N,t} = (1 - \beta_{NK}) \left(\frac{w^*_t}{p^*_{VN,t}}\right)^{-1} v^*_{N,t}, \quad l^*_{T,t} = (1 - \beta_{TK}) \left(\frac{w^*_t}{p^*_{VT,t}}\right)^{-1} v^*_{T,t} \tag{B.1.16}$$

$$x^*_{N,t} = \phi_N \left(\frac{p^*_{X,t}}{p^*_{N,t}}\right)^{-\xi} y^*_{N,t}, \quad x^*_{T,t} = \phi_T \left(\frac{p^*_{X,t}}{p^*_{T,t}}\right)^{-\xi} y^*_{T,t} \tag{B.1.17}$$

$$v^*_{N,t} = (1 - \phi_N) \left(\frac{p^*_{VN,t}}{p^*_{N,t}}\right)^{-\xi} y^*_{N,t}, \quad v^*_{T,t} = (1 - \phi_T) \left(\frac{p^*_{VT,t}}{p^*_{T,t}}\right)^{-\xi} y^*_{T,t} \tag{B.1.18}$$

Foreign investment demand:

$$i^*_t = \left(\alpha_{IT}^{\frac{1}{\epsilon}} {i^*_{T,t}}^{\frac{\epsilon-1}{\epsilon}} + (1 - \alpha_{IT})^{\frac{1}{\epsilon}} {i^*_{N,t}}^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.1.19}$$

$$i^*_{T,t} = \alpha_{IT} \left(\frac{p^*_{T,t}}{p^*_{I,t}}\right)^{-\epsilon} i^*_t, \quad i^*_{N,t} = (1 - \alpha_{IT}) \left(\frac{p^*_{N,t}}{p^*_{I,t}}\right)^{-\epsilon} i^*_t \tag{B.1.20}$$

Market clearing conditions:

$$y^*_{T,t} = c^*_{T,t} + i^*_{T,t}, \quad y^*_{N,t} = c^*_{N,t} + i^*_{N,t} \tag{B.1.21}$$

$$X^*_t = c^*_{X,t} + x^*_{T,t} + x^*_{N,t} \tag{B.1.22}$$

$$l^*_t = l^*_{T,t} + l^*_{N,t}, \quad i^*_t = i^{d*}_{T,t} + i^{d*}_{N,t} \tag{B.1.23}$$

Foreign productivity and commodity shocks:

$$\log A^*_{N,t} = (1 - \rho^*_N) \log \bar{A}^*_N + \rho^*_N \log A^*_{N,t-1} + u^*_{N,t} \tag{B.1.24}$$

$$\log A^*_{T,t} = (1 - \rho^*_T) \log \bar{A}^*_T + \rho^*_T \log A^*_{T,t-1} + u^*_{T,t} \tag{B.1.25}$$

$$\log X^*_t = (1 - \rho^*_X) \log \bar{X}^* + \rho^*_X \log X^*_{t-1} + u^*_{X,t} \tag{B.1.26}$$

B.1.2 Home economy

An equilibrium in the small commodity-exporting economy is given here.

The first-order conditions for the home representative household's problem are:

$$q_{t,t+1}U_c\left(c_t, 1-l_t\right) = \beta U_c\left(c_{t+1}, 1-l_{t+1}\right) \tag{B.1.27}$$
$$w_t U_c\left(c_t, 1-l_t\right) = U_l\left(c_t, 1-l_t\right) \tag{B.1.28}$$

Home demand on aggregate consumption good and its components:

$$c_t = \left(\alpha_{CT}^{\frac{1}{\epsilon}} c_{T,t}^{\frac{\epsilon-1}{\epsilon}} + \alpha_{CN}^{\frac{1}{\epsilon}} c_{N,t}^{\frac{\epsilon-1}{\epsilon}} + \left(1-\alpha_{CT}-\alpha_{CN}\right)^{\frac{1}{\epsilon}} c_{X,t}^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.1.29}$$
$$c_{T,t} = \alpha_{CT} p_{T,t}^{-\epsilon} c_t, \quad c_{N,t} = \alpha_{CN} p_{N,t}^{-\epsilon} c_t, \quad c_{X,t} = (1-\alpha_{CT}-\alpha_{CN}) p_{X,t}^{-\epsilon} c_t \tag{B.1.30}$$
$$c_{T,t} = \left(\alpha_{CH}^{\frac{1}{\theta}} c_{H,t}^{\frac{\theta-1}{\theta}} + (1-\alpha_{CH})^{\frac{1}{\theta}} c_{F,t}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} \tag{B.1.31}$$
$$c_{H,t} = \alpha_{CH}\left(\frac{p_{H,t}}{p_{T,t}}\right)^{-\theta} c_{T,t}, \quad c_{F,t} = (1-\alpha_{CH})\left(\frac{p_{F,t}}{p_{T,t}}\right)^{-\theta} c_{T,t} \tag{B.1.32}$$

Value added and output of the home tradable and nontradable firms and real GDP in terms of the home consumption good:

$$v_{N,t} = A_{N,t} k_{N,t}^{\beta_{NK}} l_{N,t}^{1-\beta_{NK}}, \quad v_{T,t} = A_{T,t} k_{T,t}^{\beta_{TK}} l_{T,t}^{1-\beta_{TK}} \tag{B.1.33}$$
$$y_{N,t} = \left((1-\phi_N)^{\frac{1}{\xi}} v_{N,t}^{\frac{\xi-1}{\xi}} + \phi_N^{\frac{1}{\xi}} x_{N,t}^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}} \tag{B.1.34}$$
$$y_{T,t} = \left((1-\phi_T)^{\frac{1}{\xi}} v_{T,t}^{\frac{\xi-1}{\xi}} + \phi_T^{\frac{1}{\xi}} x_{T,t}^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}} \tag{B.1.35}$$
$$y_t = p_{H,t} y_{T,t} + p_{N,t} y_{N,t} + p_{X,t}(X_t - x_{T,t} - x_{N,t}) \tag{B.1.36}$$

Capital in the home economy:

$$k_{N,t+1} = (1-\delta)k_{N,t} + k_{N,t}\Psi_k\left(\frac{i_{N,t}^d}{k_{N,t}}\right) \tag{B.1.37}$$
$$k_{T,t+1} = (1-\delta)k_{T,t} + k_{T,t}\Psi_k\left(\frac{i_{T,t}^d}{k_{T,t}}\right) \tag{B.1.38}$$

The first-order intertemporal conditions for the profit maximization problems of the home nontradable and tradable firms:

$$\beta E_t \frac{U_c\left(c_{t+1}, 1-l_{t+1}\right)}{U_c\left(c_t, 1-l_t\right)} \frac{p_{KN,t+1}}{p_{KN,t}} \left(1 + r_{N,t+1} - \delta + \Lambda_{N,t+1}\right) = 1 \tag{B.1.39}$$
$$\beta E_t \frac{U_c\left(c_{t+1}, 1-l_{t+1}\right)}{U_c\left(c_t, 1-l_t\right)} \frac{p_{KT,t+1}}{p_{KT,t}} \left(1 + r_{T,t+1} - \delta + \Lambda_{T,t+1}\right) = 1 \tag{B.1.40}$$
$$p_{KN,t} = p_{I,t}/\Psi_k'\left(\frac{i_{N,t}^d}{k_{N,t}}\right), \quad p_{KT,t} = p_{I,t}/\Psi_k'\left(\frac{i_{T,t}^d}{k_{T,t}}\right) \tag{B.1.41}$$
$$\Lambda_{N,t} = \Psi_k\left(\frac{i_{N,t}^d}{k_{N,t}}\right) - \frac{i_{N,t}^d}{k_{N,t}}\Psi_k'\left(\frac{i_{N,t}^d}{k_{N,t}}\right), \quad \Lambda_{T,t} = \Psi_k\left(\frac{i_{T,t}^d}{k_{T,t}}\right) - \frac{i_{T,t}^d}{k_{T,t}}\Psi_k'\left(\frac{i_{T,t}^d}{k_{T,t}}\right) \tag{B.1.42}$$

Capital, labor and commodity demand of the home firms:

$$k_{N,t} = \beta_{NK} \left(\frac{r_{N,t} p_{KN,t}}{p_{VN,t}} \right)^{-1} v_{N,t}, \quad k_{T,t} = \beta_{TK} \left(\frac{r_{T,t} p_{KT,t}}{p_{VT,t}} \right)^{-1} v_{T,t} \tag{B.1.43}$$

$$l_{N,t} = (1 - \beta_{NK}) \left(\frac{w_t}{p_{VN,t}} \right)^{-1} v_{N,t}, \quad l_{T,t} = (1 - \beta_{TK}) \left(\frac{w_t}{p_{VT,t}} \right)^{-1} v_{T,t} \tag{B.1.44}$$

$$x_{N,t} = \phi_N \left(\frac{p_{X,t}}{p_{N,t}} \right)^{-\xi} y_{N,t}, \quad x_{T,t} = \phi_T \left(\frac{p_{X,t}}{p_{H,t}} \right)^{-\xi} y_{T,t} \tag{B.1.45}$$

$$v_{N,t} = (1 - \phi_N) \left(\frac{p_{VN,t}}{p_{N,t}} \right)^{-\xi} y_{N,t}, \quad v_{T,t} = (1 - \phi_T) \left(\frac{p_{VT,t}}{p_{H,t}} \right)^{-\xi} y_{T,t} \tag{B.1.46}$$

Home investment demand:

$$i_t = \left(\alpha_{IT}^{\frac{1}{\epsilon}} i_{T,t}^{\frac{\epsilon-1}{\epsilon}} + (1 - \alpha_{IT})^{\frac{1}{\epsilon}} i_{N,t}^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.1.47}$$

$$i_{T,t} = \alpha_{IT} \left(\frac{p_{IT,t}}{p_{I,t}} \right)^{-\epsilon} i_t, \quad i_{N,t} = (1 - \alpha_{IT}) \left(\frac{p_{N,t}}{p_{I,t}} \right)^{-\epsilon} i_t \tag{B.1.48}$$

$$i_{T,t} = \left(\alpha_{IH}^{\frac{1}{\theta}} i_{H,t}^{\frac{\theta-1}{\theta}} + (1 - \alpha_{IH})^{\frac{1}{\theta}} i_{F,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{B.1.49}$$

$$i_{H,t} = \alpha_{IH} \left(\frac{p_{H,t}}{p_{IT,t}} \right)^{-\theta} i_{T,t}, \quad i_{F,t} = (1 - \alpha_{IH}) \left(\frac{p_{F,t}}{p_{IT,t}} \right)^{-\theta} i_{T,t} \tag{B.1.50}$$

Market clearing conditions:

$$y_{T,t} = c_{H,t} + c_{H,t}^* + i_{H,t} + i_{H,t}^*, \quad y_{N,t} = c_{N,t} + i_{N,t} \tag{B.1.51}$$

$$l_t = l_{T,t} + l_{N,t}, \quad i_t = i_{T,t}^d + i_{N,t}^d \tag{B.1.52}$$

Home productivity and commodity shocks:

$$\log A_{N,t} = (1 - \rho_N) \log \bar{A}_N + \rho_N \log A_{N,t-1} + u_{N,t} \tag{B.1.53}$$

$$\log A_{T,t} = (1 - \rho_T) \log \bar{A}_T + \rho_T \log A_{T,t-1} + u_{T,t} \tag{B.1.54}$$

$$\log X_t = (1 - \rho_X) \log \bar{X} + \rho_X \log X_{t-1} + u_{X,t} \tag{B.1.55}$$

B.1.3 International trade and prices

Foreign demand on home tradable good:

$$c_{H,t}^* = (1 - \alpha_H) \left(\frac{p_{H,t}}{p_{F,t}} \right)^{-\theta} c_{T,t}^* \tag{B.1.56}$$

$$i_{H,t}^* = (1 - \alpha_H) \left(\frac{p_{H,t}}{p_{F,t}} \right)^{-\theta} i_{T,t}^* \tag{B.1.57}$$

Trade balance of the home economy:

$$tb_t = p_{H,t}(c_{H,t}^* + i_{H,t}^*) + p_{X,t}(X_t - c_{X,t} - x_{T,t} - x_{N,t}) - p_{F,t}(c_{F,t} + i_{F,t}) \tag{B.1.58}$$

The law of one price:

$$p_{X,t} = e_t p_{X,t}^*, \quad p_{F,t} = e_t p_{T,t}^*, \quad q_{t,t+1} = \frac{e_t}{e_{t+1}} q_{t,t+1}^* \tag{B.1.59}$$

The law of one price for Arrow-Debreu securities and the first-order intertemporal conditions for the households' problems imply that:

$$e_t U_c\left(c_t, 1-l_t\right) = \vartheta_0 U_c\left(c_t^*, 1-l_t^*\right) \tag{B.1.60}$$

where ϑ_0 is constant for all times and contingencies.

B.2 The model of financial autarky

The equilibrium conditions are the same as in the model with complete markets except of the law of one price for financial assets and the intertemporal first-order conditions for the representative household's problems which are not satisfied in this model.

The only additional equilibrium condition is a balanced trade equation:

$$tb_t = p_{H,t}(c_{H,t}^* + i_{H,t}^*) + p_{X,t}(X_t - c_{X,t} - x_{T,t} - x_{N,t}) - p_{F,t}(c_{F,t} + i_{F,t}) = 0 \tag{B.2.1}$$

This model implies state and time-varying wedge ϑ_t between the cross-country marginal rate of substitution of consumption and the real exchange rate:

$$e_t U_c\left(c_t, 1-l_t\right) = \vartheta_t U_c\left(c_t^*, 1-l_t^*\right) \tag{B.2.2}$$

B.3 The model with portfolio adjustment costs

The equilibrium conditions are the same as in the model with complete markets except of the intertemporal first-order condition for the household problem, which in this model is given by the following equation:

$$q_{t,t+1} = \beta \frac{U_c\left(c_{t+1}, 1-l_{t+1}\right)}{U_c\left(c_t, 1-l_t\right)} \frac{1 + p_{N,t+1}\Psi_a'\left(E_{t+1} q_{t+1,t+2} a_{t+2} - a_{t+1}\right)}{1 + p_{N,t}\Psi_a'\left(E_t q_{t,t+1} a_{t+1} - a_t\right)} \tag{B.3.1}$$

This condition implies imperfect international risk sharing:

$$e_t U_c\left(c_t, 1-l_t\right) = \vartheta_t U_c\left(c_t^*, 1-l_t^*\right) \tag{B.3.2}$$

where

$$\vartheta_t = \frac{\vartheta_0}{1 + p_{N,t}\Psi_a'\left(E_t q_{t,t+1} a_{t+1} - a_t\right)} \tag{B.3.3}$$

Given the presence of portfolio adjustment costs, market clearing condition for the home nontradable goods is:

$$y_{N,t} = c_{N,t} + i_{N,t} + \Psi_a\left(E_t q_{t,t+1} a_{t+1} - a_t\right) \tag{B.3.4}$$

B.4 Figures

Figure B.1: Real commodity price, real exchange rate and consumption differential: Canada and Norway

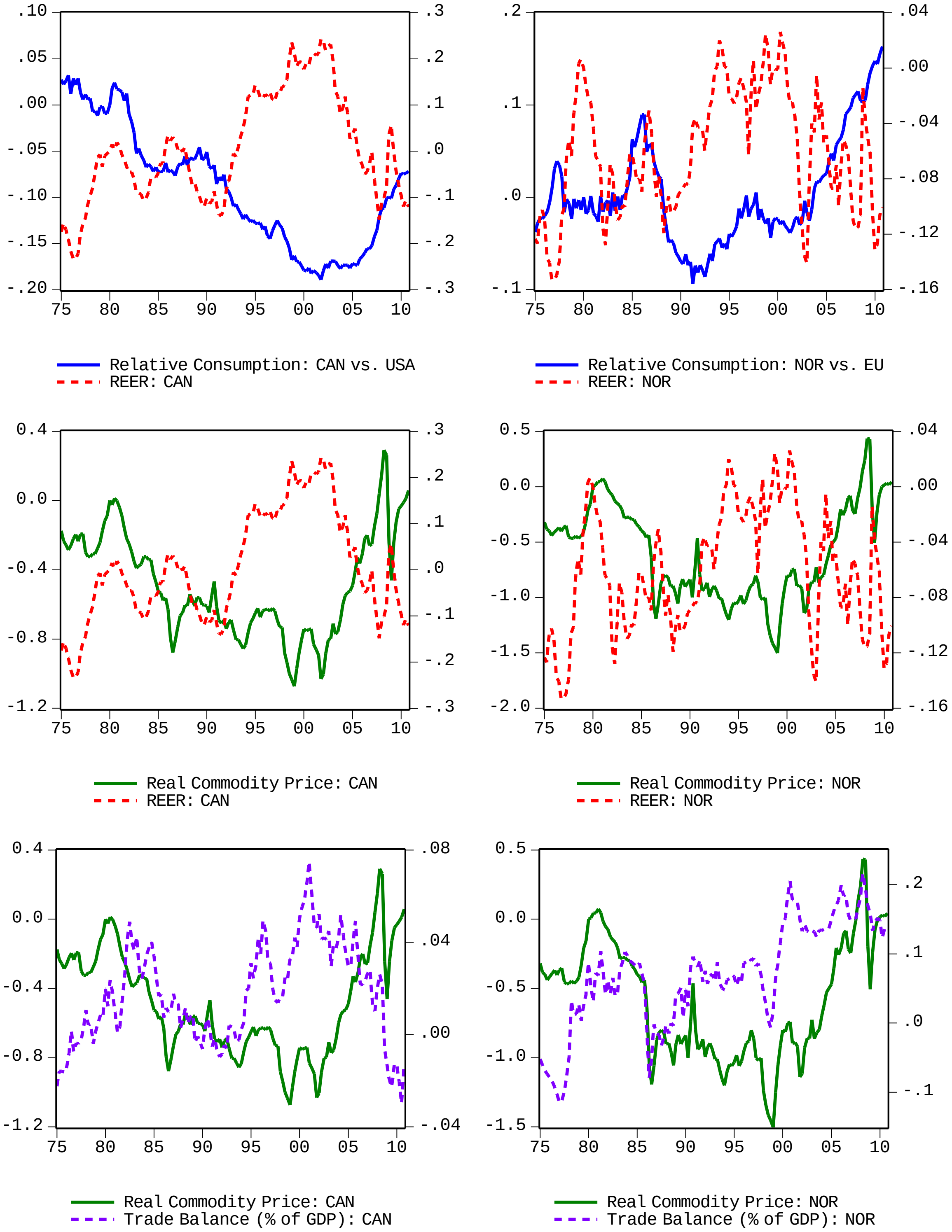


Figure B.2: Real commodity price, real exchange rate and consumption differential: Australia and New Zealand

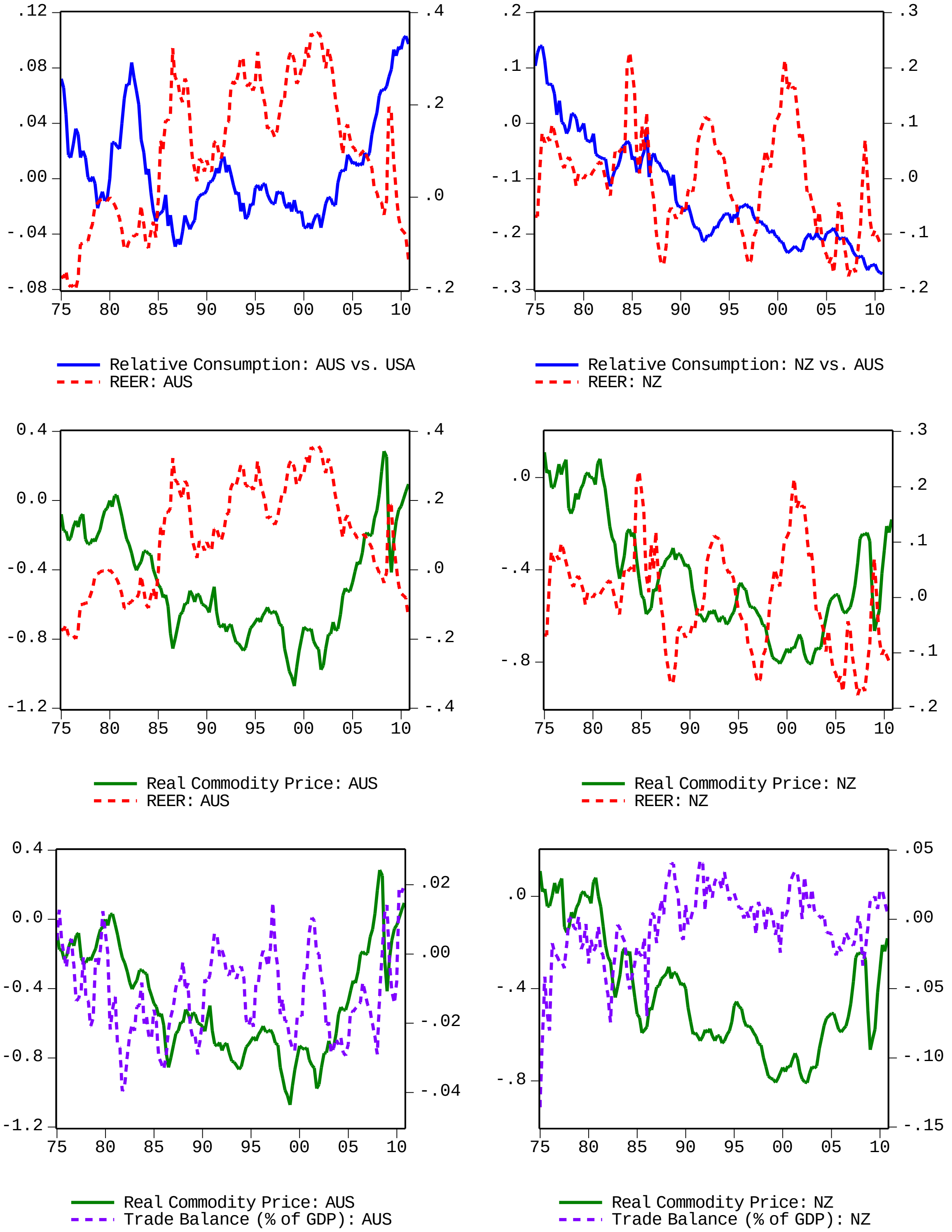


Figure B.3: International price levels in selected commodity exporting countries (% of USA)

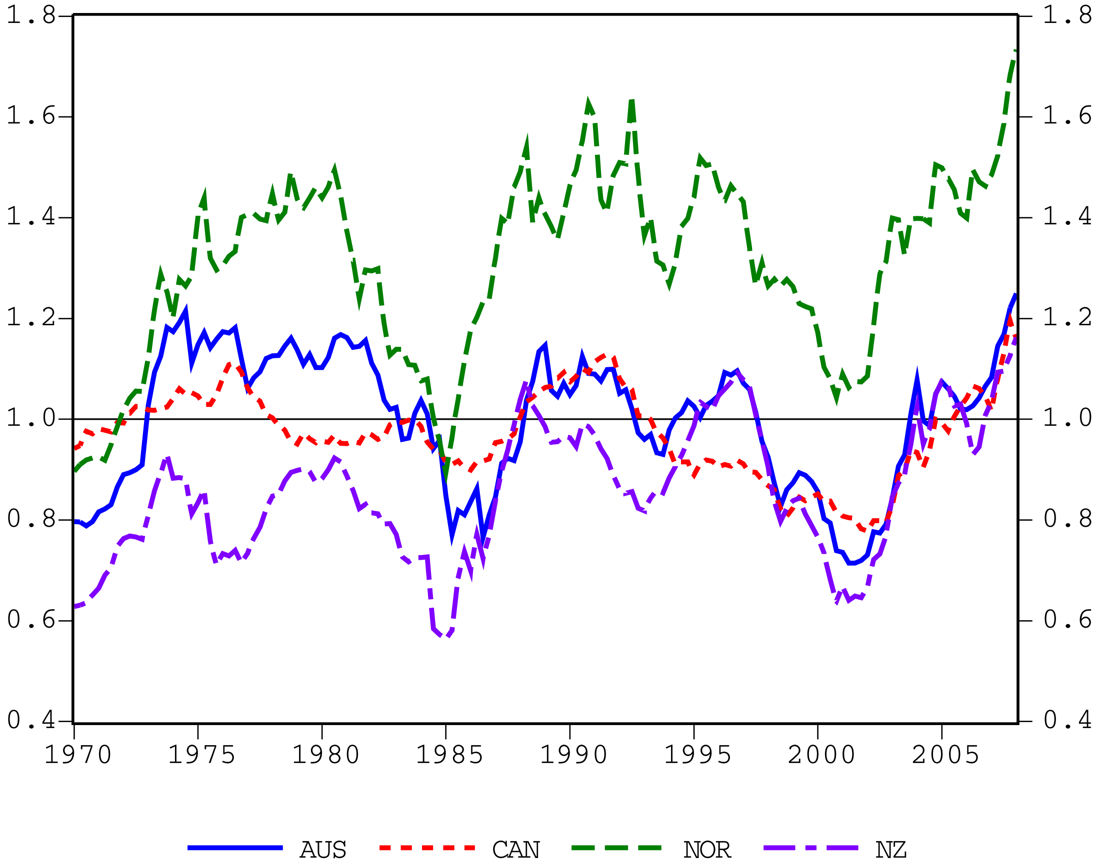
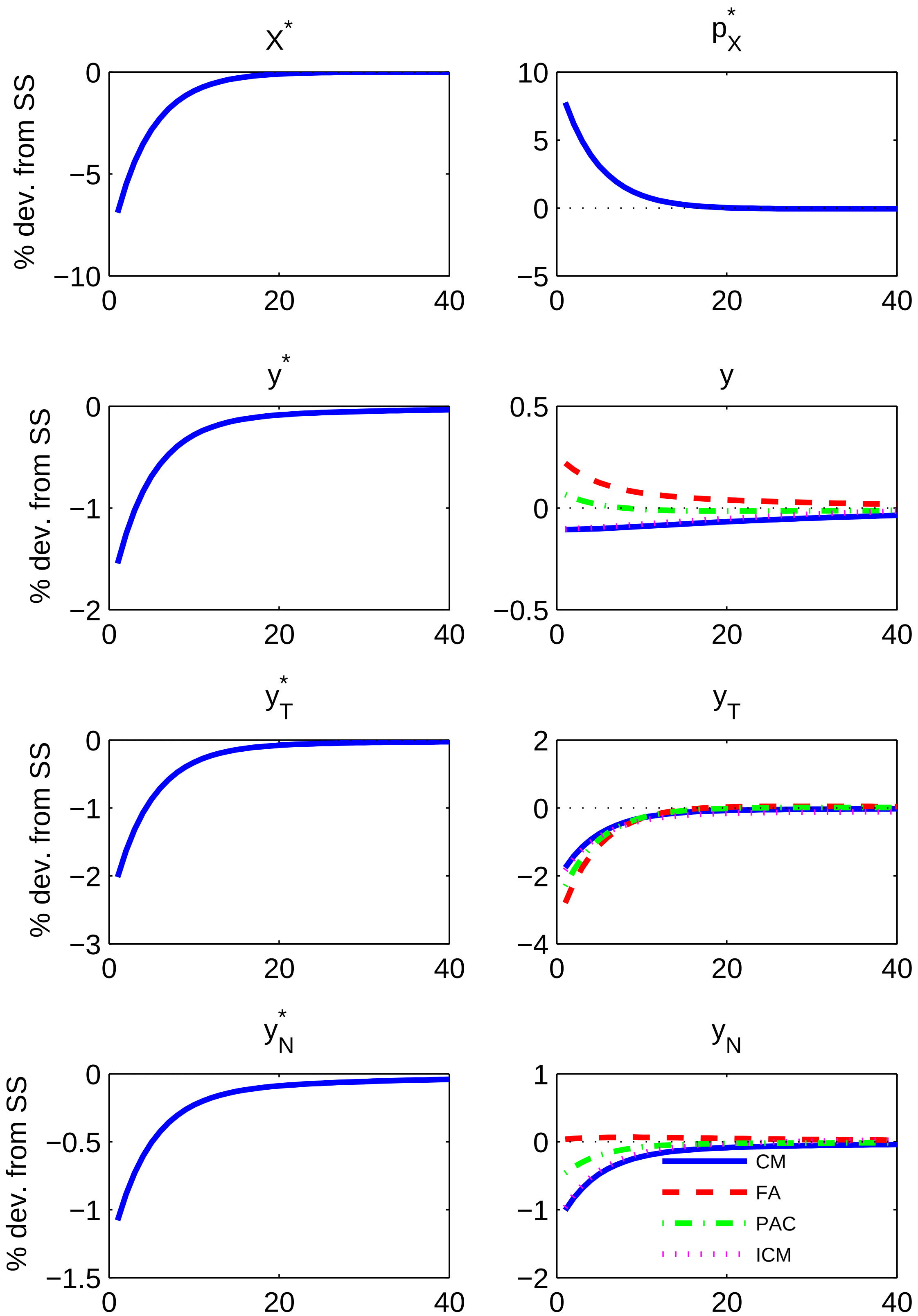
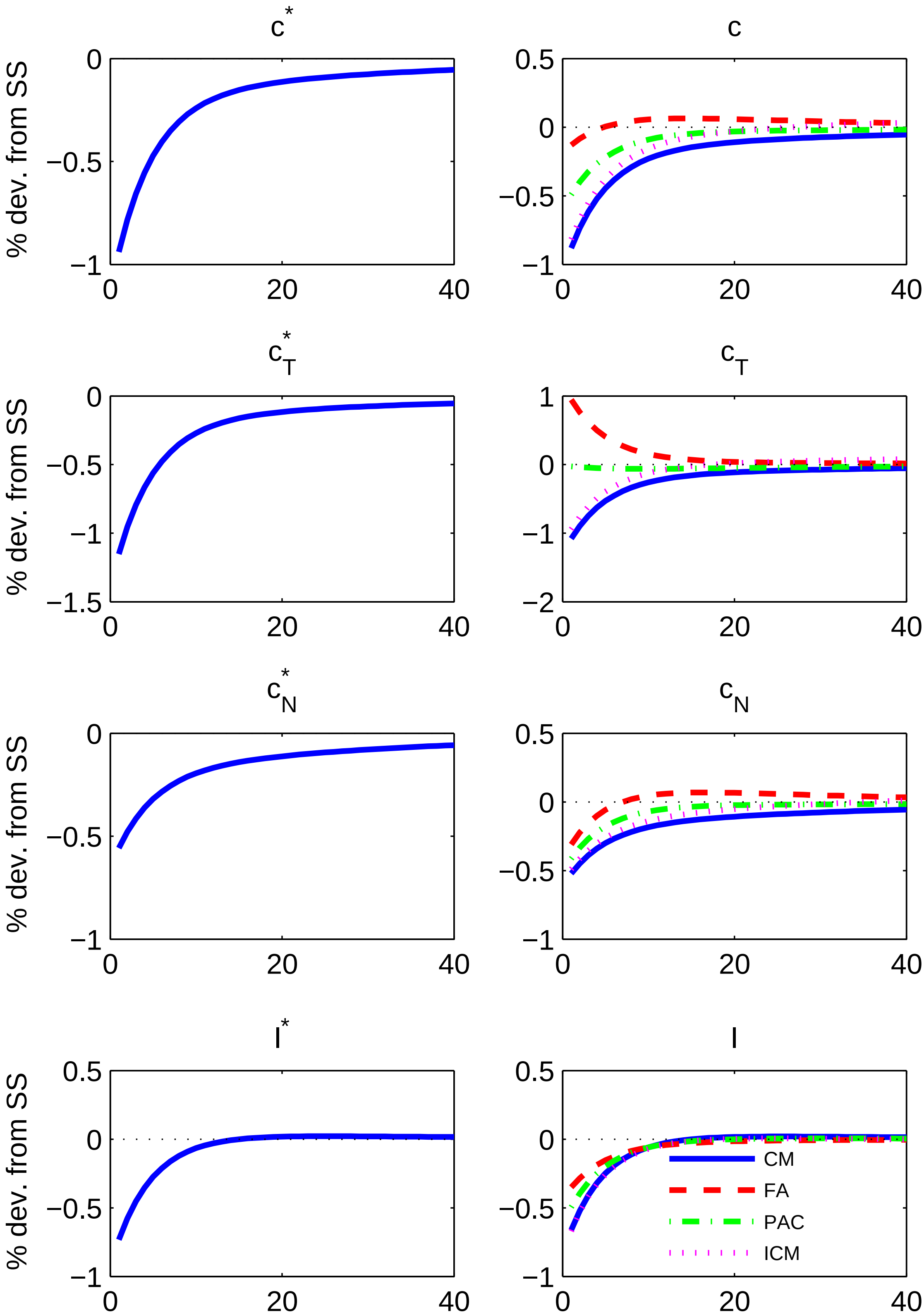


Figure B.4: Impulse responses to the foreign commodity shock



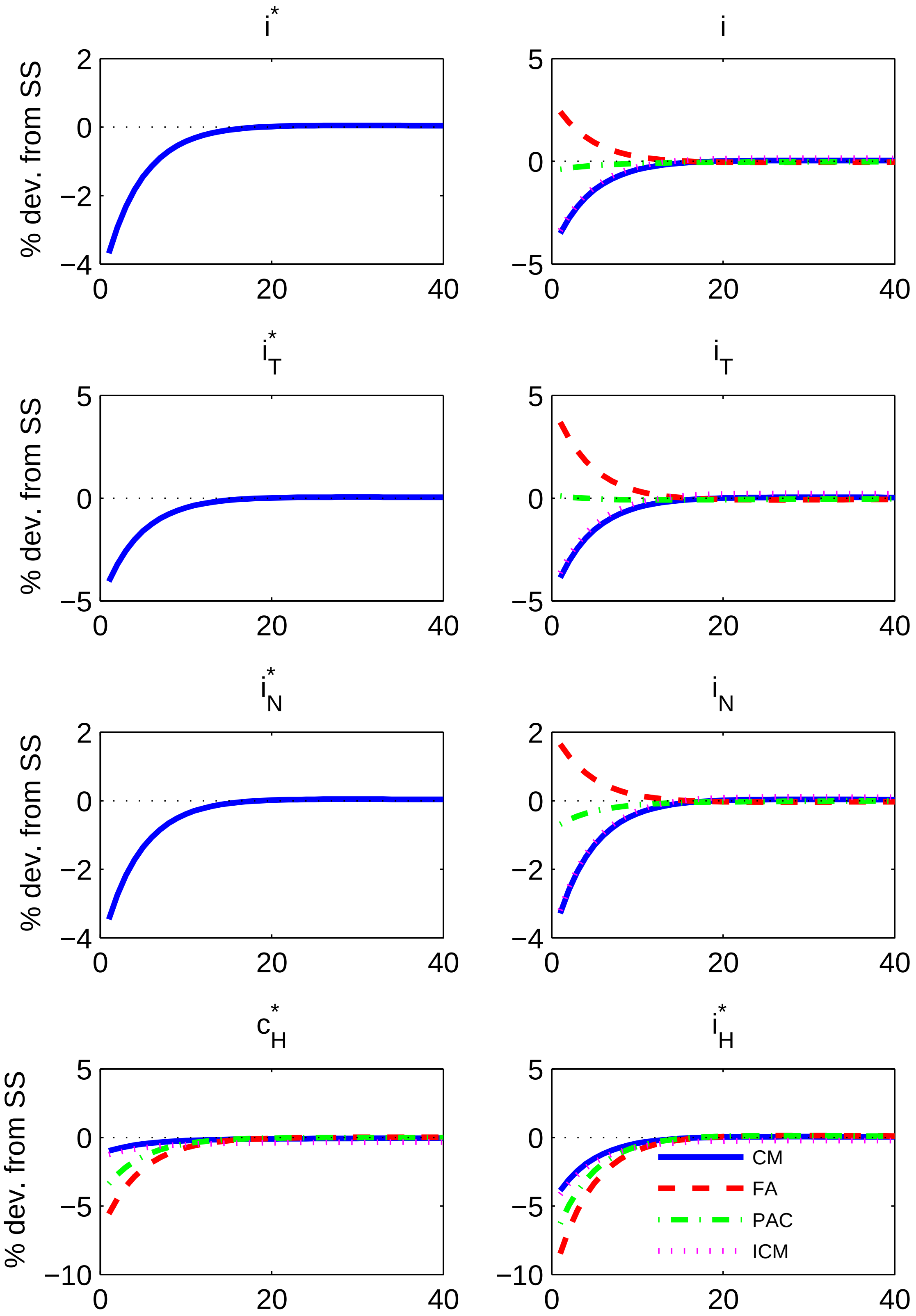
Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
X^* is a foreign commodity endowment, p_X^* is a real commodity price, y (y^*) denotes real GDP in the home (foreign) economy, y_T (y_T^*) is an output of tradable goods in the home (foreign) economy and y_N (y_N^*) denotes output of nontradable goods in the home (foreign) economy.

Figure B.5: Impulse responses to the foreign commodity shock



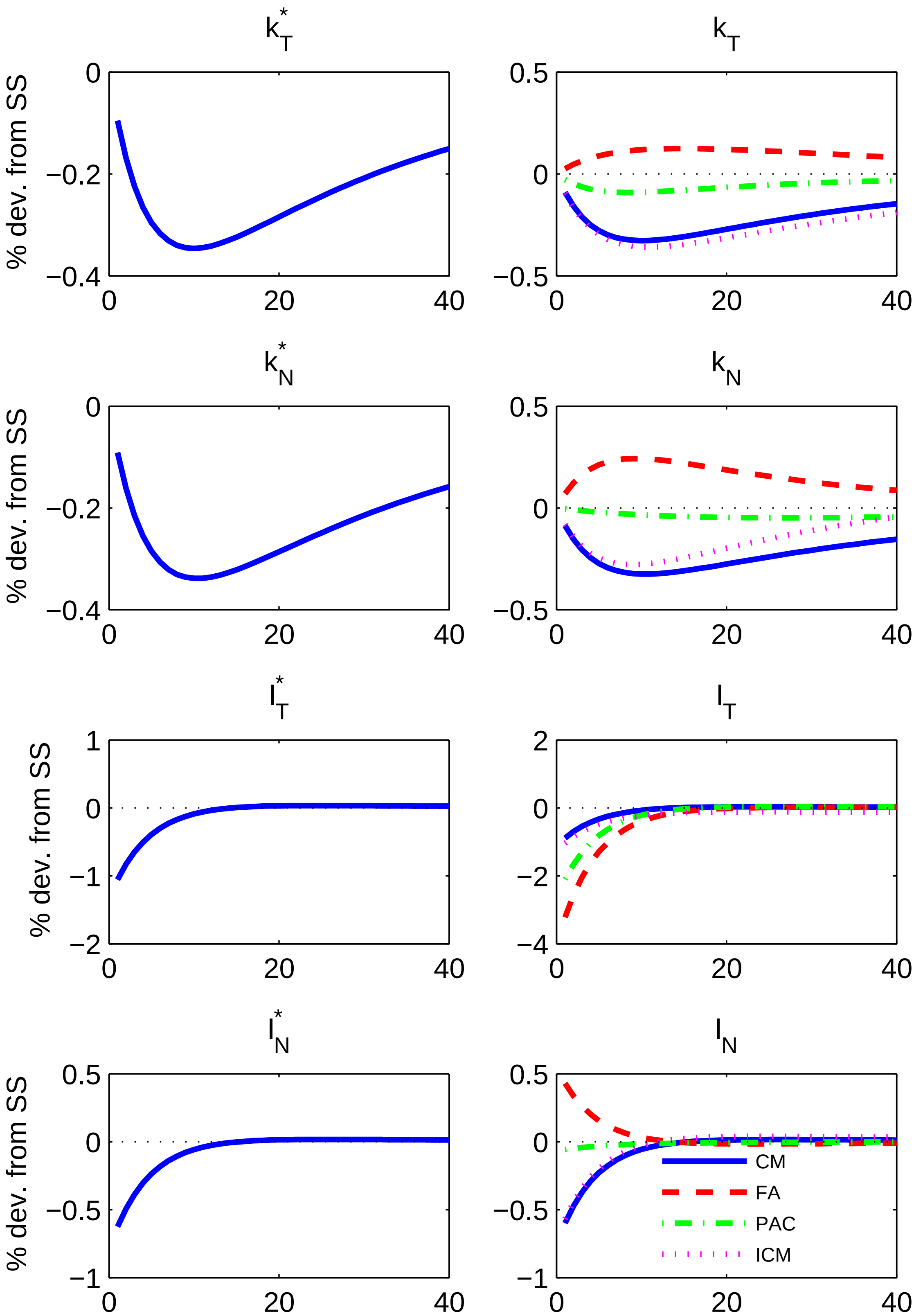
Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
c (c^*) denotes aggregate consumption in the home (foreign) economy, c_T (c_T^*) is a consumption of tradable goods, c_N (c_N^*) is a consumption of nontradable goods and l (l^*) denotes hours worked in the home (foreign) economy.

Figure B.6: Impulse responses to the foreign commodity shock



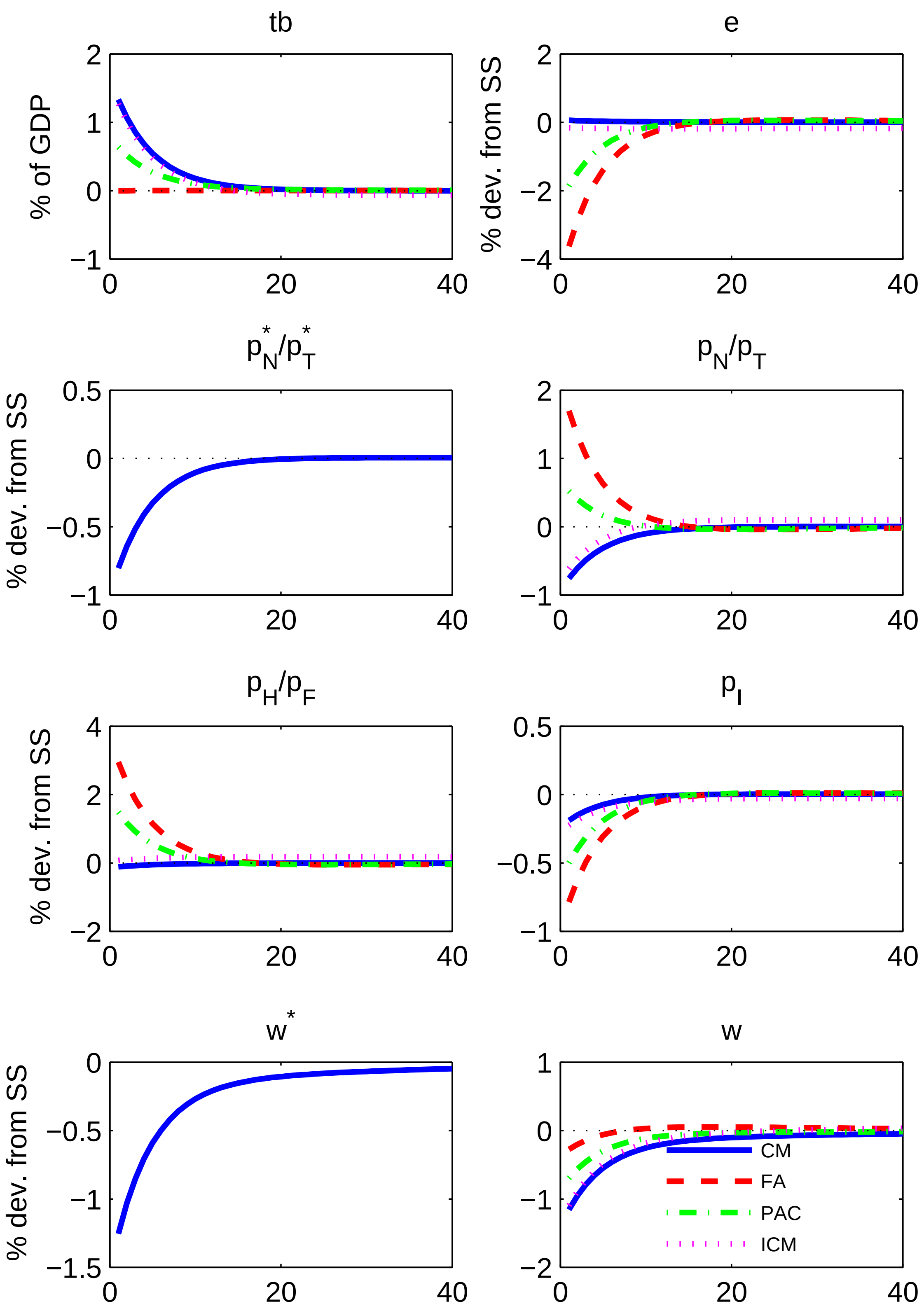
Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
i (i^*) denotes aggregate investment in the home (foreign) economy, i_T (i_T^*) is investment expenditure on tradable goods, i_N (i_N^*) is investment expenditure on nontradable goods, c_H^* and i_H^* denote respectively foreign consumer and investment demands on the home tradable goods.

Figure B.7: Impulse responses to the foreign commodity shock



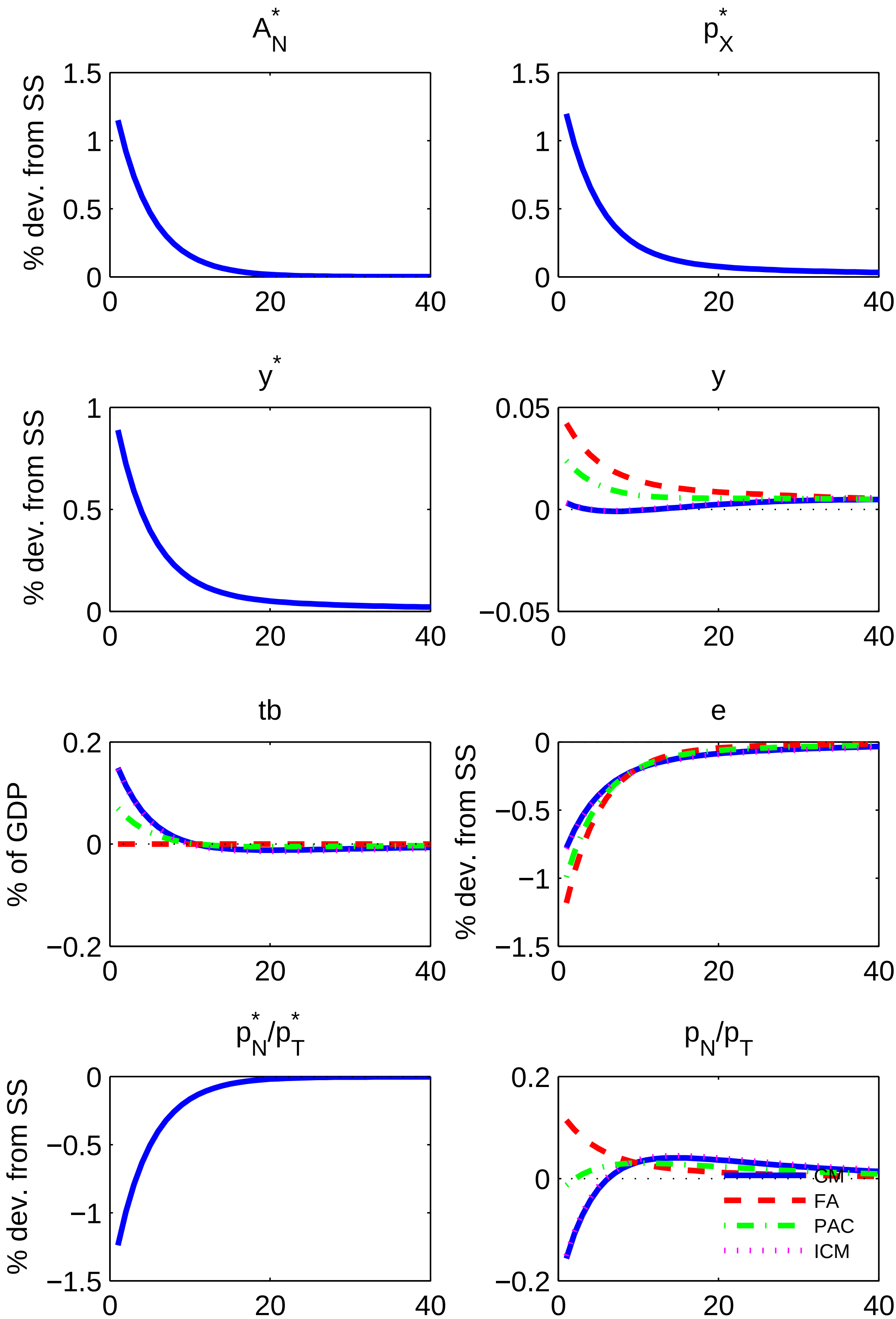
Note. CM is the model with complete markets, *FA* is the model of financial autarky, *PAC* is the model with portfolio adjustment costs, *ICM* is the model with incomplete markets.
k_T and l_T (k_T^* and l_T^*) denote capital and labor in the home (foreign) tradable sector, k_N and l_N (k_N^* and l_N^*) are capital and labor in the home (foreign) nontradable sector.

Figure B.8: Impulse responses to the foreign commodity shock



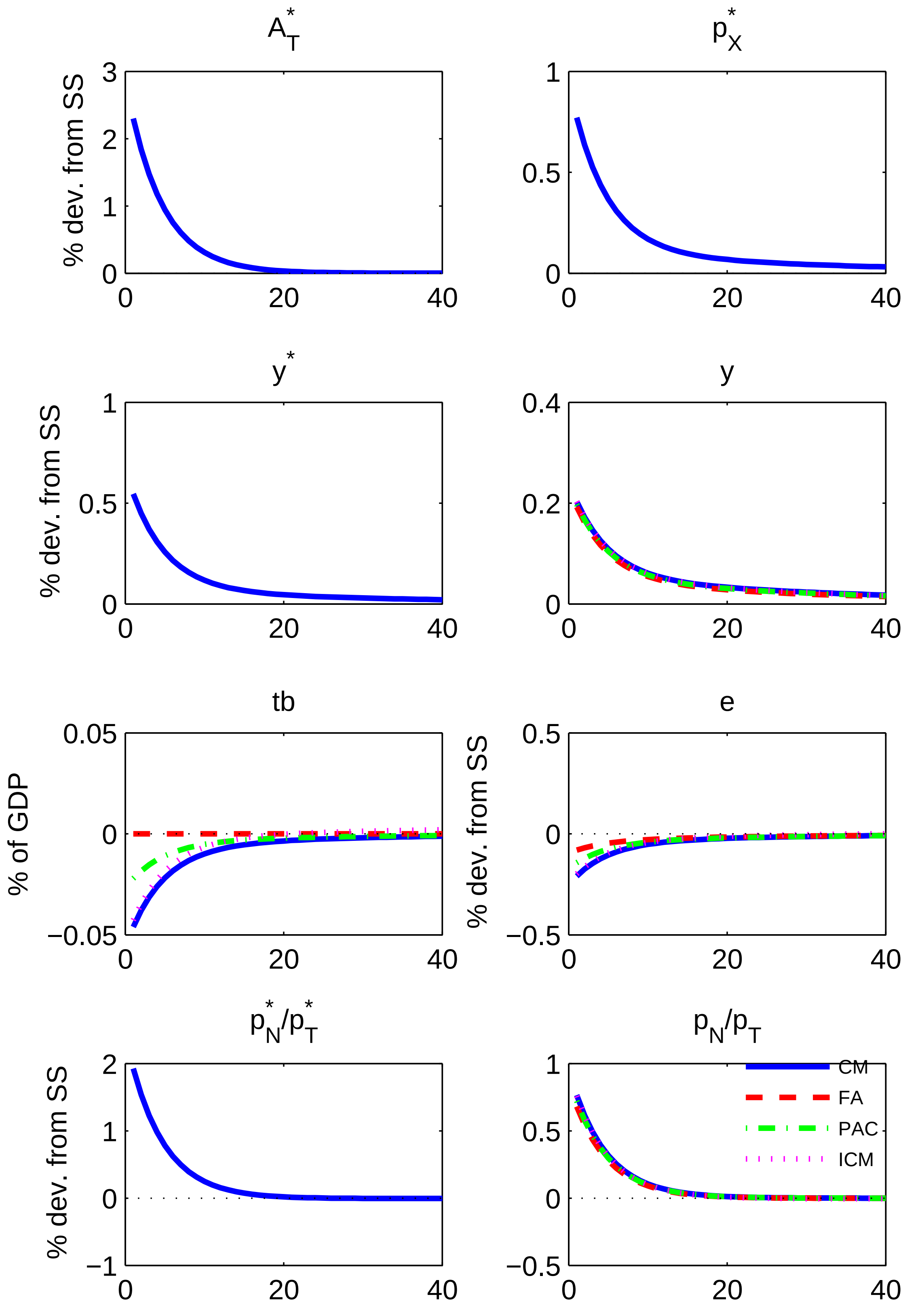
Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
tb denotes trade balance (as a share of GDP) in the home economy, e is a real exchange rate, $\frac{p_N}{p_T}$ $(\frac{p_N^*}{p_T^*})$ is a relative price of the nontradable and tradable goods in the home (foreign) economy, $\frac{p_H}{p_F}$ is a relative price of the home and foreign tradable goods, p_I denotes real investment price, w (w^*) is a real wage in the home (foreign) economy.

Figure B.9: Impulse responses to the foreign productivity shock in nontradable sector



Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
A^*_N is a productivity in the foreign nontradable sector, p^*_X is a real commodity price, y (y^*) denotes real GDP in the home (foreign) economy, tb denotes trade balance (as a share of GDP) in the home economy, e is a real exchange rate, $\frac{p_N}{p_T}$ ($\frac{p^*_N}{p^*_T}$) is a relative price of the nontradable and tradable goods in the home (foreign) economy.

Figure B.10: Impulse responses to the foreign productivity shock in tradable sector



Note. CM is the model with complete markets, FA is the model of financial autarky, PAC is the model with portfolio adjustment costs, ICM is the model with incomplete markets.
A_T^* is a productivity in the foreign tradable sector, p_X^* is a real commodity price, y (y^*) denotes real GDP in the home (foreign) economy, tb denotes trade balance (as a share of GDP) in the home economy, e is a real exchange rate, $\frac{p_N}{p_T}$ ($\frac{p_N^*}{p_T^*}$) is a relative price of the nontradable and tradable goods in the home (foreign) economy.

B.5 Tables

Table B.1: Business cycles statistics for some commodity-exporting countries

	1970Q1-2008Q1		1985Q1-2008Q1	
	Levels	HP-filtered	Levels	HP-filtered
$std(p_X)$				
Australia	29.72	8.82	22.64	8.83
Canada	27.96	9.08	22.39	9.26
Norway	39.41	14.16	34.42	15.48
New Zealand	27.35	7.95	14.45	7.32
$std(e)$				
Australia	16.62	5.68	9.98	6.06
Canada	13.69	3.52	11.31	3.47
Norway	4.45	2.69	4.22	2.60
New Zealand	9.65	5.90	10.75	6.47
$corr(c - c^*, e)$				
Australia	-0.117	-0.345	-0.284	-0.309
Canada	-0.699	-0.040	-0.746	-0.310
Norway	-0.073	0.038	-0.181	0.232
New Zealand	-0.229	-0.264	-0.283	-0.522
$corr(p_X, i)$				
Australia		0.252		0.289
Canada		0.326		0.272
Norway		-0.209		-0.238
New Zealand		0.310		0.418
$corr(p_X, e)$				
Australia	-0.865	-0.412	-0.786	-0.561
Canada	-0.681	-0.193	-0.617	-0.412
Norway	-0.478	-0.135	-0.525	-0.249
New Zealand	-0.175	-0.351	-0.578	-0.457
$corr(p_X, tb)$				
Australia		0.091		0.132
Canada		0.276		0.430
Norway		0.670		0.785
New Zealand		0.005		0.200

Note. All the variables except trade balance are in logarithms. p_X is real world price index of exported commodities, y is GDP in terms of consumption good, i is investment, $c - c^*$ is consumption differential with main trade partner, e is effective real exchange rate and tb is trade balance in % of GDP.
Data. OECD EO, EcoWin

Table B.2: Calibration

Parameters		Value
Preferences	β	0.99
	γ	0.38
	σ	2
Aggregates	ϵ	0.74
	θ	1.5
	a_{CT}	0.23
	a_{CN}	0.73
	a_{CH}	0.68
	a_{IT}	0.38
	a_{IH}	0.31
Technology	δ	0.025
	ξ	0.69
	b_{TK}	0.34
	b_{NK}	0.34
	ϕ_T	0.20
	ϕ_N	0.10
	A_T^*	3.13
	A_N^*	3.13
	X^*	1.00
	A_T	2.47
	A_N	2.88
	X	1.41
Shocks	$\rho_X,\ \rho_X^*$	0.80
	$std(u_X),\ std(u_X^*)$	4.60, 6.90
	$\rho_T,\ \rho_T^*$	0.80
	$std(u_T),\ std(u_T^*)$	2.30, 2.30
	$\rho_N,\ \rho_N^*$	0.80
	$std(u_N),\ std(u_N^*)$	1.15, 1.15
Adjustment costs	ψ	0.6
	d	-0.005

Table B.3: Breakdown of industries into commodity, tradable and nontradable sectors: Canada, 2000

ISIC code	Industry	Value added (% of GDP)	Trade turnover (% of Gross output)	Net export (% of Gross output)	MFP (% of US)
Primary commodity industries		**16.3**	**70.0**	**16.4**	**98**
A,B	Agriculture, hunting, forestry and fishing	2.2	29.8	7.4	65
C	Mining and quarrying	6.1	75.8	31.6	102
D20	Wood and products of wood and cork	1.3	64.9	49.1	100
D21-22	Pulp, paper, printing and publishing	2.5	65.0	26.4	114
D23	Coke, refined petroleum products and nuclear fuel	0.2	31.0	8.7	67
D24	Chemicals and chemical products	1.4	116.1	-23.2	97
D25	Rubber and plastics products	0.9	99.8	14.4	73
D26	Other non-metallic mineral products	0.5	64.7	-11.6	106
D27	Basic metals	1.2	91.7	10.4	123
Tradable good industries		**28.6**	**81.5**	**-2.5**	**79**
D15-16	Food products, beverages and tobacco	2.1	43.8	3.4	102
D17-20	Textiles, textile products, leather and footwear	0.8	141.4	-41.1	80
D28	Fabricated metal products	1.4	83.3	-4.2	69
D29	Machinery and equipment, n.e.c	1.3	206.0	-62.1	99
D30	Office, accounting and computing machinery	0.1	387.3	-126.9	78
D31	Electrical machinery and apparatus, n.e.c.	0.7	233.0	-72.8	83
D32	Radio, television and communication equipment	0.5	165.9	21.0	83
D33	Medical, precision and optical instruments	0.3	230.9	-87.1	83
D34	Motor vehicles, trailers and semi-trailers	2.5	152.3	9.2	128
D35	Other transport equipment	0.9	144.0	18.9	128
D36-37	Furniture, manufacturing n.e.c., recycling	0.7	114.6	18.0	73
I60-63	Transport	4.0	28.2	21.2	88
J	Finance and insurance	6.2	16.5	-6.1	66
K72	Computer and related activities	1.3	27.1	16.0	66
K74	Other business activities	5.8	23.8	-3.2	59
Nontradable good industries		**55.1**	**5.9**	**2.8**	**92**
E	Electricity, gas and water supply	2.6	13.1	9.5	60
F	Construction	5.0	0.0	0.0	135
G	Wholesale and retail trade, repairs	13.3	9.8	6.0	91
H	Hotels and restaurants	2.3	21.7	10.4	93
I64	Post and telecommunications	2.5	11.7	0.6	68
K70-71,73	Real estate, renting, research and development	11.9	1.5	0.0	66
L	Public admin. and defense, comp. social security	7.2	1.1	1.0	99
M	Education	4.7	1.5	1.2	118
N	Health and social work	2.4	1.4	-1.3	118
O	Other community, social and personal services	3.1	13.3	4.1	64
P,Q	Private households with employed persons	0.2	0.0	0.0	118

Table B.4: Steady state equilibrium

	Variable	Foreign	Home
Output			
GDP	y	6.46	6.23
production of tradables	y_T	1.69	1.19
production of nontradables	y_N	4.57	4.37
production of commodity	X	1.00	1.41
Consumption			
total	c	5.14	4.99
tradables	c_T	1.18	1.16
home tradables	c_H		0.66
foreign tradables	c_F		0.53
nontradables	c_N	3.75	3.60
commodity	c_X	0.21	0.24
Investment			
total	i	1.32	1.30
tradables	i_H	0.50	0.53
home tradables	i_F		0.11
foreign tradables	i_H		0.43
nontradables	i_F	0.82	0.77
Capital			
total	k	52.93	51.82
in tradable sector	k_T	13.06	11.08
in nontradable sector	k_N	39.87	40.74
Employment			
total	l	0.30	0.29
in tradable sector	l_T	0.07	0.06
in nontradable sector	l_N	0.23	0.23
Commodity input			
in tradable sector	x_T	0.34	0.31
in nontradable sector	x_N	0.46	0.52
Export			
home tradables			0.43
for consumption	c_H^*		0.22
for investment	i_H^*		0.20
commodity			0.34
Import			
foreign tradables			0.95
Price of tradables	p_T	1.00	0.99
of home tradables	p_H		1.12
of foreign tradables	p_F		0.78
Price of nontradables	p_N	1.00	1.02
Price of capital goods	p_K	1.00	0.96
Commodity price	p_X	1.00	0.78
Wage	w	11.99	11.53
Capital return	r	0.04	0.04
Real exchange rate	e		0.78

Table B.5: Business cycles statistics

Statistics	Data	Model							
	Canada	Foreign		Home					
	1985Q1-2008Q1			Complete Markets		Financial Autarky		Adjustment Costs	
Standard Dev.									
GDP	1.78	2.24	(.06)	1.55	(.03)	1.71	(.04)	1.62	(.04)
Output of tradables	4.19[1]	3.31	(.08)	3.47	(.08)	4.40	(.12)	3.92	(.09)
Output of nontradables	1.69[1]	1.86	(.05)	1.91	(.05)	1.54	(.04)	1.56	(.04)
Consumption	0.91	1.32	(.04)	1.31	(.03)	0.92	(.02)	0.99	(.03)
Investment	4.12	5.75	(.15)	5.70	(.14)	6.09	(.16)	4.13	(.11)
Employment	1.12	0.95	(.03)	0.86	(.02)	0.56	(.01)	0.68	(.02)
Trade balance (% of GDP)	0.91			1.90	(.05)	0.00	(.)	0.90	(.02)
Real commodity price	9.26	9.51	(.25)						
Real exchange rate	3.47			1.39	(.04)	5.56	(.15)	3.18	(.08)
Cross-correlations									
Between real commodity price and									
GDP	0.58	-0.71	(.02)	-0.06	(.03)	0.17	(.03)	0.06	(.03)
Output of tradables	-0.08[1]	-0.64	(.02)	-0.61	(.02)	-0.77	(.02)	-0.71	(.02)
Output of nontradables	0.02[1]	-0.56	(.02)	-0.62	(.02)	0.03	(.04)	-0.35	(.03)
Investment	0.27	-0.65	(.02)	-0.72	(.02)	0.50	(.03)	-0.08	(.04)
Real exchange rate	-0.41			-0.07	(.04)	-0.81	(.01)	-0.76	(.02)
Trade balance	0.43			0.84	(.01)	0.00	(.)	0.84	(.01)
Between real exchange rate and									
Relative consumption	-0.31			1.00	(.)	-0.45	(.03)	0.04	(.03)
Between foreign and home									
GDP	0.62			0.12	(.04)	-0.07	(.03)	0.01	(.03)
Consumption	0.63			0.66	(.02)	0.15	(.04)	0.50	(.02)
Investment	0.49			0.70	(.02)	-0.23	(.03)	0.26	(.03)
Employment	0.70			0.88	(.01)	0.74	(.02)	0.85	(.01)

[a] annual data

Table B.6: Business cycles statistics: foreign commodity shocks

Statistics	Model							
	Foreign		Home					
			Complete Markets		Financial Autarky		Adjustment Costs	
Standard Dev.								
GDP	1.86	(.05)	0.14	(.)	0.26	(.01)	0.08	(.)
Trade balance (% of GDP)			1.61	(.04)	0.00	(.)	0.77	(.02)
Real commodity price	9.39	(.26)						
Real exchange rate			0.07	(.)	4.38	(.12)	2.26	(.06)
Cross-correlations								
Between real commodity price and								
GDP			-0.85	(.01)	0.98	(.)	0.99	(.)
Real exchange rate			0.99	(.)	-1.00	(.)	-1.00	(.)
Trade balance			1.00	(.)	0.00	(.)	1.00	(.)
Between real exchange rate and								
Relative consumption			1.00	(.)	-0.98	(.)	-0.98	(.)

Table B.7: Business cycles statistics: foreign productivity shocks in tradable sector

Statistics	Model							
	Foreign		Home					
			Complete Markets		Financial Autarky		Adjustment Costs	
Standard Dev.								
GDP	0.66	(.02)	0.24	(.01)	0.23	(.01)	0.24	(.01)
Trade balance (% of GDP)			0.06	(.)	0.00	(.)	0.03	(.)
Real commodity price	0.93	(.03)						
Real exchange rate			0.25	(.01)	0.10	(.)	0.17	(.)
Cross-correlations								
Between real commodity price and								
GDP			1.00	(.)	1.00	(.)	1.00	(.)
Real exchange rate			-1.00	(.)	-0.99	(.)	-1.00	(.)
Trade balance			-1.00	(.)	0.00	(.)	-1.00	(.)
Between real exchange rate and								
Relative consumption			1.00	(.)	1.00	(.)	1.00	(.)

Table B.8: Business cycles statistics: foreign productivity shocks in nontradable sector

Statistics	Model							
	Foreign		Home					
			Complete Markets		Financial Autarky		Adjustment Costs	
Standard Dev.								
GDP	1.07	(.03)	0.00	(.)	0.05	(.)	0.03	(.)
Trade balance (% of GDP)			0.18	(.)	0.00	(.)	0.09	(.)
Real commodity price	1.44	(.04)						
Real exchange rate			0.94	(.03)	1.43	(.04)	1.20	(.03)
Cross-correlations								
Between real commodity price and								
GDP			0.59	(.02)	0.99	(.)	0.99	(.)
Real exchange rate			-1.00	(.)	-1.00	(.)	-1.00	(.)
Trade balance			0.99	(.)	0.00	(.)	0.99	(.)
Between real exchange rate and								
Relative consumption			1.00	(.)	1.00	(.)	1.00	(.)

Table B.9: Sensitivity analysis

Statistics	X			θ			$std(u_X^*)$		
	1	1.41	3	0.74	1.5	15	4.6	6.9	9.2
Standard Dev.									
GDP	1.56	1.62	1.85	1.55	1.62	1.96	1.62	1.62	1.62
Output of tradables	3.97	3.92	3.70	2.95	3.92	9.31	3.31	3.92	4.61
Output of nontradables	1.60	1.56	1.53	1.57	1.56	1.52	1.50	1.56	1.63
Consumption	1.06	0.99	0.89	1.01	0.99	0.94	0.89	0.99	1.12
Investment	4.09	4.13	4.67	4.02	4.13	4.70	4.11	4.13	4.16
Employment	0.80	0.68	0.47	0.64	0.68	1.16	0.52	0.68	0.86
Trade balance (% of GDP)	0.82	0.90	0.98	0.85	0.90	1.17	0.71	0.90	1.13
Real commodity price	9.51	9.51	9.51	9.55	9.51	9.55	6.47	9.51	12.61
Real exchange rate	2.74	3.18	4.24	3.39	3.18	3.08	2.71	3.18	3.76
Cross-correlations									
Between real commodity price and									
GDP	-0.16	0.06	0.37	-0.04	0.06	0.33	0.05	0.06	0.08
Investment	-0.28	-0.08	0.28	-0.17	-0.08	0.15	-0.03	-0.08	-0.12
Real exchange rate	-0.71	-0.76	-0.81	-0.72	-0.76	-0.74	-0.64	-0.76	-0.84
Trade balance	0.83	0.84	0.86	0.83	0.84	0.82	0.72	0.84	0.90
Between real exchange rate and									
Relative consumption	0.23	0.04	-0.25	0.16	0.04	-0.19	0.27	0.04	-0.17
Between foreign and home									
GDP	0.19	0.01	-0.24	0.13	0.01	-0.24	0.04	0.01	-0.02
Consumption	0.56	0.50	0.32	0.52	0.50	0.38	0.30	0.50	0.63
Investment	0.40	0.26	-0.04	0.34	0.26	0.06	0.25	0.26	0.27
Employment	0.88	0.85	0.60	0.86	0.85	0.68	0.72	0.85	0.90

Chapter 3

International risk sharing and optimal monetary policy in a small commodity-exporting economy

3.1 Introduction

It is commonly acknowledged that high volatility in commodity prices has important effects on global economic activity. However, less attention has been paid to analyze the effect of this volatility on small commodity-exporting economies, where primary resources constitute an essential source of export revenues. In these countries, commodity-price movements have enormous impacts on a wide range of macroeconomic variables, including balance of payments, exchange rates, output and public finance. As a result, these effects pose serious problems for the conduct of macroeconomic policy in such economies.

In particular, it has been stressed in the literature (Chen and Rogoff, 2003; Cashin et al., 2004) that real exchange rates in commodity-exporting economies exhibit two salient regularities: (i) they are very volatile and (ii) they are negatively correlated with world commodity prices. Hence, price hikes of basic commodities are usually associated with a real exchange rate appreciation and, conversely, price drops are linked to a real depreciation. This empirical regularity is known in economic literature as the *commodity currency* effect, a phenomenon which is illustrated in Figure C.1 for four developed commodity-exporting countries: Canada, Norway, Australia and New Zealand.[1]

Moreover, commodity currency effect poses a problem for the conduct of monetary policy in such economies since fluctuations of the real exchange rate induced by commodity price changes render impossible the joint achievement of stable prices and stable nominal

[1]Standard deviations of the real commodity price index, real effective exchange rate and their cross-correlations (for HP-filtered series) for the period 1985q1-2008q1 are respectively: 9.3, 3.5 and -0.41 for Canada, 15.5, 2.6 and -0.25 for Norway, 8.8, 6.1 and -0.56 for Australia, 7.3, 6.5 and -0.46 for New Zealand.

exchange rate.[2] Accordingly, there is a trade-off between these two basic goals of monetary policy and the choice of the nominal exchange rate regime (flexible vs. fixed) has nontrivial welfare implications. Given that inflation is very costly in an environment with sticky consumer prices, a common suggestion in the open-economy literature is to allow the nominal exchange rate to float freely in these economies, absorbing in this way the volatile terms-of-trade shocks (e.g., this type of policy recommendation has been made for Canada and Russia in Dib (2008) and Sosunov and Zamulin (2007), respectively).

In line with this prescription, many central banks in commodity-exporting economies have adopted a goal of low and stable inflation. For instance, all developed commodity-exporting economies (Australia, Canada, Norway, New Zealand and Iceland) and many fast-growing emerging economies (Chile, Brazil, South Africa) pursue an explicit core inflation target while the nominal exchange rate is allowed to float freely in order to act as a shock absorber. There are, however, exceptions to this rule like many Gulf oil producers which peg their currencies to US dollar or Russia and Kazakhstan which manage the nominal exchange rate fluctuations using interventions (partially sterilized) in the foreign exchange markets. The monetary policy authorities in these countries often claim that the main rationale for these operations is to reduce volatility of the real exchange rate and to alleviate the danger of a Dutch disease.[3] Nonetheless, it is often the case that this policy succeeds in smoothing real exchange rate fluctuations, but at the cost of a high (often two-digit) and unstable inflation.

In view of these different monetary policy experiences, the goal of this chapter is to analyze under which conditions the adoption of a fixed nominal exchange rate might not be such a bad policy per se for small commodity-exporting economies. In particular, I argue that the volatility of the real exchange rate and, as a result, the welfare costs of the fixed regime depend crucially on the extent of risk sharing between the commodity-exporting economy and the rest of the world. One can think of two alternative setups. On the one hand, under the assumption of complete and frictionless asset markets, such an economy may be perfectly insured against foreign commodity shocks, rendering no significant effects on the real exchange rate so that welfare losses from the fixed nominal exchange rate become negligible. On the other hand, the existence of frictions in international assets trade renders too costly a complete insurance against foreign commodity shocks. In such a case, the windfall income gains from commodity exports are spent partially at home

[2]Note, that the rate of change of the real exchange rate is given (in logs) by $\Delta q_t = \Delta e_t + \pi_t^* - \pi_t$, where Δe_t is the rate of change of the nominal exchange rate, and π_t and π_t^* denote domestic and foreign inflation respectively. So, under an assumption of stable foreign prices, fluctuations in the real exchange rate have to be accommodated either by changes in the nominal exchange rate, or by domestic inflation/deflation.

[3]Dutch disease is an economic concept that explains the relationship between the increase in export revenues from basic commodities and a decline in the non-commodity tradable sector (mainly manufacturing). The underlying mechanism is the following. An increase in export of primary commodities will appreciate real exchange rate, making non-commodity exports more expensive. As a result, the manufacturing sector becomes less competitive and its output declines (see Corden, 1984, for more details).

and this puts pressure on the real exchange rate so that welfare costs of the fixed nominal exchange rate regime might be large.

Specifically, to analyze quantitatively the welfare effects of the world commodity price shocks under alternative regimes of the monetary policy, I propose a multi-sector New Keynesian model of small commodity-exporting economy which can be calibrated to estimate the welfare costs in each situation. This model features three production sectors: primary commodity, non-commodity tradable and nontradable sectors. The world economy is modeled explicitly as in Gali and Monacelli (2005) and Charnavoki (2009). Therefore in contrast to the existing literature for small commodity-exporting economies (for example Dib, 2008; Sosunov and Zamulin, 2007), the world commodity price fluctuations in this model (as well as the other world prices and demands) are not treated as shocks per se, but are rather considered to be endogenously determined outcomes. This allows us to control directly the extent of international risk sharing. The representative households trade a complete set of financial assets, but portfolio pay-offs bear transaction costs. By varying the degree of financial transaction costs, it is possible to cover a full spectrum of model economies ranging from perfect international risk sharing to financial autarky.[4]

The formulation of the proposed model takes into consideration several stylized features of primary commodities which have been highlighted in this strand of the literature. First, primary commodities are assumed to be a homogeneous good in the sense that many firms supply goods with similar characteristics and qualities that are traded in organized exchanges or have a reference price (Rauch, 1999). By contrast, tradable and nontradable goods are produced in varieties, differentiated both across and within countries.

Secondly, while prices of primary commodities are very flexible (Bils and Klenow, 2004; Gopinath and Rigobon, 2008), there is significant heterogeneity in the frequencies of price changes for manufactured goods and services.[5] Therefore, nominal prices of primary

[4]Our model is related to the existing theoretical literature studying international risk-sharing, namely Backus-Smith and real exchange rate volatility puzzles, in the context of two-country models. A number of papers explain these puzzles using models with incomplete asset markets. So, for example, Benigno and Thoenissen (2007) study a model with nontradable and tradable goods sectors. To obtain a negative correlation between relative consumption and the real exchange rate they assume that productivity shocks to the tradable sector are more persistent and more volatile than those in the nontradable one. Corsetti, Dedola, and Leduc (2008) argue that the implied elasticity of substitution between tradable goods is low since nontradable goods are used in the distribution of tradables. This feature allows them to solve Backus-Smith and real exchange rate volatility puzzles in the model with single traded asset. However, an assumption of incomplete asset markets in stochastic framework of small open economy model results in non-stationary equilibrium dynamics. To induce stationarity standard models usually assume non-separable preferences or some form of frictions in assets trade (Schmitt-Grohe and Uribe, 2003). Yet, these additional elements might resolve the aforementioned puzzles in the framework with complete markets too. For example, Bodenstein (2008) develops a two-country model with complete asset markets and limited enforcement for international financial contracts that provides a possible explanation of these two puzzles. At the same time, Verdelhan (2010) uses habit preferences to explain excess volatility of the real exchange rate.

[5]Bils and Klenow (2004) report that in US 54.3% prices of raw goods are changed every month comparing to 20.5% prices of processed goods and 20.7% prices of services. Gopinath and Rigobon (2008) use US export/import data and estimate monthly frequencies of price changes 83%(73%) and 30%(27%)

commodities in the model are asummed to be flexible, whereas price rigidities in the non-commodity tradable and nontradable sectors are modelled using conventional Calvo-Yun contracts. It is also assumed that a fraction of prices of exported non-commodity goods is quoted in foreign currency (local currency pricing) while the rest is quoted in domestic currency (producer-currency pricing).

Lastly, output and labor productivity of industries producing primary commodities (agriculture, fishing, mining, etc.) are significantly more volatile than in manufacturing, services or construction (see global sector-specific shocks in Koren and Tenreyro, 2007). This can be observed in Table C.1 which presents, for a sample of OECD countries, the standard deviations of labor productivity in commodity-production sectors (agriculture, fishing, mining, etc.), as well as in tradable (manufacturing) and nontradable (services, utilities and construction) sectors. Labor productivity in the commodity sector is on average twice and four times more volatile than in the tradable and nontradable sectors, respectively. Together with an inelastic demand on commodities, this fact could explain an excess volatility of the commodity prices.

While monetary policy in the rest of the world is supposed to be conducted in an optimal way, four monetary policy regimes are considered for small commodity-exporting economy: credible peg of the nominal exchange rate, targeting core consumer inflation,[6] targeting domestic non-commodity output inflation and optimal policy with commitment. For the welfare computations, we use a second-order approximations to the welfare and policy functions around the deterministic steady state following the approach advocated by Schmitt-Grohe and Uribe (2004).[7]

The welfare comparisons of the alternative monetary policy regimes are related to the existing distortions. In this respect, I abstract from the monopolistic distortion that induces an inefficient level of output by introducing offsetting subsidy, and instead focus on other two sources of inefficiency to trade off in our model of small commodity-exporting economy. First, in response to asymmetric disturbances, nominal rigidities create an inefficient dispersion of prices within tradable and nontradable sectors as well as an inefficient path of the domestic and international (terms of trade, real exchange rates) relative prices. Second, financial frictions generate a wedge between the marginal utility differential in the home and world economies and real exchange rate, resulting in demand disequilibria (in terminology of Corsetti, Dedola, and Leduc, 2010). Further, in the case of local currency pricing, there are deviations from the law of one price, resulting in inefficiency in the supply of tradable goods due to price dispersion in domestic and foreign markets. Finally,

for import(export) goods traded on organized exchanges and having reference price respectively comparing to 7%(7%) for differentiated import(export) goods.

[6] Core CPI does not include primary commodity component.

[7] A standard welfare analysis of the model of open economy using second-order approximation to the welfare function but linear approximation to policy function may provide spurious results (see Kim and Kim, 2003).

as stressed by many authors (see in particular Corsetti and Pesenti (2001) and Benigno and Benigno (2003)), there is strategic element in open-economy monetary policy since monetary authorities may affect terms of trade in a beneficial for home economy way.

The main findings are the following. In accordance with the existing literature, the welfare comparisons show that a fixed nominal exchange rate regime is, in general, dominated by a flexible regime. However, the welfare costs of the fixed regime vary significantly with the extent of international risk sharing and with the size of home commodity sector. As discussed earlier, under assumption of complete and frictionless asset markets, welfare losses from the nominal peg are small. Alternatively, if the commodity sector is too small, the home economy cannot generate significant windfall income from commodity exports so that, even under financial autarky, the fixed regime is not very costly. In sum, it is only in the case of a large commodity sector and imperfect financial markets that a fixed regime implies high welfare costs.

This result underscores the practical importance for small commodity-exporting economies of adopting some kind of cross-country risk-sharing mechanisms, which would allow them to stabilize their real exchange rates while reducing the welfare costs of keeping the nominal exchange rate pegged. In practice this may be implemented by either hedging in commodity futures markets,[8] or creating some form of the stabilization fund,[9] or even participating in a full-fledged fiscal union (see Frankel, 2010, for a good review).

Another relevant implication of our analysis is related to the welfare properties of the flexible nominal exchange rate regimes. We show that core consumer inflation targeting and non-commodity domestic inflation targeting turn out to be not optimal in general, though their welfare costs are small comparing to fixed regime. Further, the welfare ranking of these two regimes may depend on the currency in which tradable goods are priced (producer currency pricing vs. local currency pricing). Under producer currency pricing domestic inflation targeting is preferable to core consumer inflation targeting while the opposite holds under local currency pricing.

This rest of the chapter is organized as follows. Section 2 presents the main features of the model for a small commodity-exporting economy. Section 3 discusses calibration of the parameters and shocks. Section 4 reports and discusses simulations results: deterministic steady-state, impulse responses to unitary innovations in foreign commodity shocks and the main business cycle statistics. Section 5 measures and discusses the welfare implications of the alternative monetary policy regimes. Section 6 concludes.

[8]Believing oil prices would eventually fall, Mexico hedged in 2008 almost all of next's year oil exports at prices ranging from $70 to $100 at a cost of about $1.5bn through derivatives contracts. According to Financial Times, this move paid off handsomely, resulting in over $5bn in profit when the price of oil collapsed in 2009.

[9]At present time, many resource-abundant countries and regions accumulate a fraction of their commodity revenues in sovereign wealth funds. We can recall here, for instance, Government Pension Fund of Norway, Reserve Fund of Russia, Alaska Permanent Fund, Permanent Wyoming Mineral Trust Fund or Alberta Heritage Fund.

3.2 Model

This section starts by presenting a model of the world economy in its more general format. Next, specific assumptions about productivities, commodity endowments and monetary policies are made to reduce this model to the small commodity-exporting economy/the world economy case.

Notation is as follows. Variables with an i subscript refer to economy i, one among the continuum of economies making up the world economy. Variables without an i-index denote a small commodity-exporting economy being modelled. Finally, variables with a star superscript correspond to the world economy as a whole (typical foreign economy).

3.2.1 General description of the model

The world economy is modeled as a continuum of small open economies represented by a unit interval, as in Gali and Monacelli (2005). Since each economy is of measure zero, its domestic policy decisions do not have any impact on the rest of the world. We abstract here from the monetary frictions and interpret this model as cashless limiting case (see Woodford, 2003). Assets markets therefore are complete.

A typical small economy produces three types of goods: differentiated *tradable* good, differentiated *nontradable* good and homogeneous tradable primary *commodity*. Tradable goods and commodity can be used for consumption either in the domestic economy or abroad, whereas nontradable goods are consumed only in the home country. Firms producing tradable and nontradable goods, as well as commodity endowments, are owned by domestic households.

The world economy is affected by productivity shocks in tradable and nontradable sectors as well as by shocks to commodity endowments.

3.2.2 Households

A typical small economy i is inhabited by a representative household who owns domestic tradable and nontradable firms and supplies labor to them. This household maximizes expected life-time utility:

$$\max_{\{C_t(i),L_{N,t}(i),L_{T,t}(i),D_{t+1}(i,s_{t+1})\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}(i)}{1-\sigma} - \chi_N^{-\nu}(i) \frac{L_{N,t}^{1+\nu}(i)}{1+\nu} - \chi_T^{-\nu}(i) \frac{L_{T,t}^{1+\nu}(i)}{1+\nu} \right) \tag{3.2.1}$$

subject to a sequence of budget constraints expressed in terms of domestic currency:

$$\begin{aligned} &P_t(i)C_t(i) + \int Q_{t,t+1}(i,s_{t+1})D_{t+1}(i,s_{t+1})ds_{t+1} + P_{N,t}(i)\Psi\left(\frac{D_t(i)}{P_t(i)}\right) \leq \\ &\leq D_t(i) + W_{N,t}(i)L_{N,t}(i) + W_{T,t}(i)L_{T,t}(i) + \Pi_t(i) - T_t(i) \end{aligned} \tag{3.2.2}$$

where $C_t(i)$ is a consumption, $L_{k,t}(i)$ denotes hours worked in sector $k \in \{N, T\}$, $D_{t+1}(i, s_{t+1})$ are the holdings of state-contingent claims, priced at $Q_{t,t+1}(i, s_{t+1})$, paying off one unit of domestic currency in the realized state of the world s_{t+1}, $P_t(i)$ denotes a consumption price index, $W_{k,t}(i)$ is nominal wage in sector k, $\Pi_t(i)$ denotes profits from the domestic firms and commodity endowment and $T_t(i)$ are lump-sum taxes/transfers.[10]

Note, that labor is imperfectly mobile between domestic tradable and nontradable firms. We assign the weights $\chi_T(i)$ and $\chi_N(i)$ in such a way, that wages in both sectors would be equalized in a deterministic steady-state equilibrium.

Given the assumption of the complete assets markets, the currency composition of financial assets can be ignored. So, to simplify notation, only the nominal pay-offs denominated in domestic currency are posted here. Prices of the state-contingent claims paying off in currency i and j are linked in the following way:

$$Q_{t,t+1}(i) = Q_{t,t+1}(j)\frac{\mathcal{E}_t(i,j)}{\mathcal{E}_{t+1}(i,j)} \tag{3.2.3}$$

where $\mathcal{E}_t(i, j)$ is bilateral nominal exchange rate (price of currency j in terms of currency i).

The convex function $\Psi(s)$ reflects the financial intermediation costs and satisfies the following assumptions: $\Psi(s) \geq 0$, $\Psi(0) = \Psi'(0) = 0$ and $\Psi''(0) = \psi > 0$. In particular, I assume quadratic costs: $\Psi(s) = \psi\frac{s^2}{2}$. These transaction costs allow us to control risk sharing between domestic and foreign economies. In the limit, when $\psi \to \infty$, economy i becomes an financial autarky. Another extreme case: $\psi = 0$, corresponds to perfect international risk sharing.[11] Without loss of generality, we assume also that these financial intermediation costs are paid in terms of nontradable goods.

The composite consumption good C_t is a CES basket of the tradable $C_{T,t}$, nontradable $C_{N,t}$ goods and commodity $C_{X,t}$:

$$C_t(i) = \left(\alpha_T^{\frac{1}{\epsilon}} C_{T,t}^{\frac{\epsilon-1}{\epsilon}}(i) + \alpha_N^{\frac{1}{\epsilon}} C_{N,t}^{\frac{\epsilon-1}{\epsilon}}(i) + (1-\alpha_T-\alpha_N)^{\frac{1}{\epsilon}} C_{X,t}^{\frac{\epsilon-1}{\epsilon}}(i)\right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.2.4}$$

[10] Note that money does not appear in the budget constraint. We assume here that central bank can directly control nominal short-run interest rate paid on risk-free assets. Hence, money plays here only the role of unit of account.

[11] The model of small open economy with incomplete markets and null transaction costs ($\psi = 0$) is characterized by nonstationary equilibrium dynamics (in contrast to complete markets case). Non-zero financial intermediation costs may be used to make price of the debt sensitive to its size and therefore to avoid nonstationarity issue. See Schmitt-Grohe and Uribe (2003) for alternative ways to deal with nonstationarity in the model of small open economy.

where ϵ denotes an elasticity of substitution between tradable goods, nontradable goods and commodity (gross complementarity is assumed: $\epsilon < 1$) and α_T and α_N reflect the weights of tradable and nontradable goods in composite index.

The index of tradable goods $C_{T,t}$ is in turn a CES basket of the home $C_{H,t}$ and foreign $C_{F,t}$ tradable goods:

$$C_{T,t}(i) = \left(\alpha_H^{\frac{1}{\theta}} C_{H,t}^{\frac{\theta-1}{\theta}}(i) + (1-\alpha_H)^{\frac{1}{\theta}} C_{F,t}^{\frac{\theta-1}{\theta}}(i)\right)^{\frac{\theta}{\theta-1}} \tag{3.2.5}$$

where θ is the elasticity of substitution between home and foreign tradable goods (with $\epsilon < \theta$) and α_H reflects a home bias in consumption of tradable goods.

Nontradable, home tradable and foreign tradable indexes, $C_{N,t}$, $C_{H,t}$ and $C_{F,t}$ respectively, are aggregates of varieties:

$$\begin{aligned} C_{N,t}(i) &= \left(\int_0^1 C_{N,t}^{\frac{\eta_N-1}{\eta_N}}(i,n)dn\right)^{\frac{\eta_N}{\eta_N-1}}, \quad C_{H,t}(i) = \left(\int_0^1 C_{T,t}^{\frac{\eta_T-1}{\eta_T}}(i,i,h)dh\right)^{\frac{\eta_T}{\eta_T-1}} \\ C_{F,t}(i) &= \left(\int_{0,j\neq i}^1 \int_0^1 C_{T,t}^{\frac{\eta_T-1}{\eta_T}}(i,j,h)dhdj\right)^{\frac{\eta_T}{\eta_T-1}} \end{aligned} \tag{3.2.6}$$

where $C_{N,t}(i,n)$ is country i consumption of nontradable variety n, $C_{T,t}(i,j,h)$ is country i consumption of tradable variety h produced in country j, η_N and η_T are the elasticities of substitution among varieties in nontradable and tradable sectors respectively.

Households allocate their consumption by solving expenditure minimization problem (taking prices of goods as given).

3.2.3 Firms and commodity endowments

The markets for tradable and nontradable goods in the model are characterized by monopolistic competition. It is assumed that the only variable factor of production is labor.

Typical firms producing nontradable and tradable goods have the following production functions:

$$Y_{N,t}(i,n) = A_{N,t}(i)L_{N,t}(i,n), \quad Y_{T,t}(i,h) = A_{T,t}(i)L_{T,t}(i,h) \tag{3.2.7}$$

where $A_{N,t}(i)$ and $A_{T,t}(i)$ are productivity levels, respectively, in nontradable and tradable sectors in the country i, $L_{N,t}$ and $L_{T,t}$ are labor inputs.

Staggered pricing a-la Calvo-Yun in nontradable and tradable sectors are assumed (Calvo, 1983). In particular, a fraction $0 < \omega_N < 1$ of nontradable goods prices remains unchanged each period, whereas new prices are optimally chosen for the other fraction $1 - \omega_N$ of nontradable goods.

Since the firms are owned by domestic households, the present value of future profits is discounted according to the household's intertemporal marginal rate of substitution in consumption:

$$\mathcal{F}_{t,\tau}(i) = \beta^{\tau-t}\left(\frac{C_\tau(i)}{C_t(i)}\right)^{-\sigma}\frac{P_t(i)}{P_\tau(i)} \tag{3.2.8}$$

A firm that changes its price in period t chooses $\mathcal{P}_{N,t}(i)$ to maximize the expected discounted stream of profits:

$$\max_{\{\mathcal{P}_{N,t}(i)\}} E_t \sum_{\tau=t}^{\infty} \omega_N^{\tau-t}\mathcal{F}_{t,\tau}(i)\left(\mathcal{P}_{N,t}(i) - (1-s_N)\frac{W_{N,\tau}(i)}{A_{N,\tau}(i)}\right)\left(\frac{\mathcal{P}_{N,t}(i)}{P_{N,\tau}(i)}\right)^{-\eta_N} Y_{N,\tau}(i) \tag{3.2.9}$$

where $Y_{N,\tau}(i) = C_{N,\tau}(i) + \frac{1}{2}\psi\left(\frac{D_\tau(i)}{P_\tau(i)}\right)^2$ is aggregate demand on nontradable goods.

To induce an efficient level of output government subsidizes the firms with rate s_N and finances this subsidy by lump-sum taxes on domestic households.

The price index of nontradable goods $P_{N,t}(i)$ is then determined as:

$$P_{N,t}(i) = \left(\omega_N P_{N,t-1}^{1-\eta_N}(i) + (1-\omega_N)\mathcal{P}_{N,t}^{1-\eta_N}(i)\right)^{\frac{1}{1-\eta_N}} \tag{3.2.10}$$

Pricing decisions of the tradable firms are more complicated, given that these firms can set their prices either in home or in foreign currency. It is assumed here that a share γ of all domestic firms in that sector use producer currency pricing (PCP). These firms solve the following problem:

$$\begin{aligned}&\max_{\{\mathcal{P}_{T,t}^P(i)\}} E_t \sum_{\tau=t}^{\infty} \omega_T^{\tau-t}\mathcal{F}_{t,\tau}(i)\left(\mathcal{P}_{T,t}^P(i) - (1-s_T)\frac{W_{T,\tau}(i)}{A_{T,\tau}(i)}\right)\times \\ &\times\left(\left(\frac{\mathcal{P}_{T,t}^P(i)}{P_{H,\tau}(i)}\right)^{-\eta_T} C_{H,\tau}(i) + \int_{0,j\neq i}^{1}\left(\frac{\mathcal{P}_{T,t}^P(i)}{\mathcal{E}_\tau(i,j)P_{F,\tau}(j)}\right)^{-\eta_T} C_{F,\tau}(j)dj\right)\end{aligned} \tag{3.2.11}$$

where s_T is an offsetting subsidy to tradable firms.

The remaining fraction $1-\gamma$ of domestic tradable firms set their prices using local currency pricing (LCP):

$$\begin{aligned}&\max_{\{\mathcal{P}_{T,t}^L(i,j)\}_j} E_t \sum_{\tau=t}^{\infty} \omega_T^{\tau-t}\mathcal{F}_{t,\tau}(i)\Bigg\{\left(\mathcal{P}_{T,t}^L(i,i) - (1-s_T)\frac{W_\tau(i)}{A_{T,\tau}(i)}\right)\left(\frac{\mathcal{P}_{T,t}^L(i,i)}{P_{H,\tau}(i)}\right)^{-\eta_T} C_{H,\tau}(i) + \\ &+\int_{0,j\neq i}^{1}\left(\mathcal{E}_\tau(i,j)\mathcal{P}_{T,t}^L(i,j) - (1-s_T)\frac{W_\tau(i)}{A_{T,\tau}(i)}\right)\left(\frac{\mathcal{P}_{T,t}^L(i,j)}{P_{F,\tau}(j)}\right)^{-\eta_T} C_{F,\tau}(j)dj\Bigg\}\end{aligned} \tag{3.2.12}$$

where $\mathcal{P}_{T,t}^L(i,j)$ are the optimal prices chosen by tradable firms of country i using LCP for their export to country j.

The indices of home and foreign tradable goods are then determined as:

$$\begin{aligned} P_{H,t}^{1-\eta_T}(i) &= \omega_T P_{H,t-1}^{1-\eta_T}(i) + (1-\omega_T)\gamma \mathcal{P}_{T,t}^{P1-\eta_T}(i) + (1-\omega_T)(1-\gamma)\mathcal{P}_{T,t}^{L1-\eta_T}(i,i) \\ P_{F,t}^{1-\eta_T}(i) &= \omega_T P_{F,t-1}^{1-\eta_T}(i) + (1-\omega_T)\gamma \int_{0,j\neq i}^{1} \left(\mathcal{E}_t(i,j)\mathcal{P}_{T,t}^{P}(j)\right)^{1-\eta_T} dj + \\ &+ (1-\omega_T)(1-\gamma) \int_{0,j\neq i}^{1} \mathcal{P}_{T,t}^{L1-\eta_T}(j,i) dj \end{aligned} \tag{3.2.13}$$

where $\mathcal{P}_{T,t}^{P}(i)$ and $\mathcal{P}_{T,t}^{L}(i,j)$ are optimal prices chosen by tradable firms of country i in period t using, respectively, producer currency and local currency pricing.

Output in commodity sector is exogenously determined and does not incur costs. Therefore, the profits of this sector are just the commodity endowment X_t times its price $P_{X,t}$:

$$\Pi_{X,t}(i) = P_{X,t}(i) X_t(i) \tag{3.2.14}$$

3.2.4 Governments

The budget constraint of the government in country i is given by the following equation:

$$T_t(i) = s_N W_{N,t}(i) L_{N,t}(i) + s_T W_{T,t}(i) L_{T,t}(i) \tag{3.2.15}$$

where $T_t(i)$ are lump-sum taxes levied on domestic households to finance offsetting subsidies $s_k W_{k,t}(i) L_{k,t}(i)$ to firms in sector $k \in \{T, N\}$.

3.2.5 Market clearing conditions

All goods, factors and assets markets clear at any time and any contingency.

Market clearing for the tradable, nontradable goods and commodity requires:

$$\begin{aligned} Y_{N,t}(i,n) &= C_{N,t}(i,n) + \left(\frac{P_{N,t}(i,n)}{P_{N,t}(i)}\right)^{-\eta_N} \frac{\psi}{2} \left(\frac{D_t(i)}{P_t(i)}\right)^2, \forall i,n,t \\ Y_{T,t}(i,h) &= \int_0^1 C_{T,t}(j,i,h) dj, \forall i,h,t, \quad \int_0^1 X_t(i) di = \int_0^1 C_{X,t}(i) di, \forall t \end{aligned} \tag{3.2.16}$$

The aggregate supply of the labor has to be equal to the aggregate demand of labor in both nontradable and tradable sectors:

$$L_{N,t}(i) = \int_0^1 L_{N,t}(i,n) dn, \forall i,t, \quad L_{T,t}(i) = \int_0^1 L_{T,t}(i,h) dh, \forall i,t \tag{3.2.17}$$

Finally, the total supply of assets in the world economy is zero at any time and any contingency:

$$\int_0^1 D_t(i,s_t)\mathcal{E}_t(j,i)di = 0, \forall j,t,s_t \qquad (3.2.18)$$

3.2.6 Productivity and commodity shocks

So far we have presented a very general model of the world economy. To specify this model for the small commodity-exporting economy/the world economy case we need to introduce several assumptions about productivities, commodity endowments and monetary policy.

First of all, among the continuum of small open economies we choose one economy of measure zero labeled as home economy. All other (foreign) economies are completely symmetric: they are driven by the same productivities in nontradable and tradable sectors, $A^*_{N,t}$ and $A^*_{T,t}$, and commodity endowments, X^*_t. Besides, they share a common currency. As a result, a typical foreign economy represents the world economy as whole.

The home economy is assumed to be commodity abundant:

$$\bar{A}_N = \bar{A}^*_N, \;\; \bar{A}_T = \bar{A}^*_T, \;\; \bar{X} > \bar{X}^* \qquad (3.2.19)$$

where $\bar{A}_T(\bar{A}^*_T)$, $\bar{A}_N(\bar{A}^*_N)$, and $\bar{X}(\bar{X}^*)$ denote steady-state productivity of tradable and nontradable firms and commodity endowments in home (foreign) country respectively.

The commodity and productivity shocks in home and world economies are assumed to follow independent AR(1) processes:

$$\begin{aligned}
&\log A_{k,t} = (1-\rho_k)\bar{A}_k + \rho_k \log A_{k,t-1} + u_{k,t}, \; k \in \{N,T\} \\
&\log X_t = (1-\rho_X)\bar{X} + \rho_X \log X_{t-1} + u_{X,t} \\
&\log A^*_{k,t} = (1-\rho_k)\bar{A}^*_k + \rho_k \log A^*_{k,t-1} + u^*_{k,t}, \; k \in \{N,T\} \\
&\log X^*_t = (1-\rho_X)\bar{X}^* + \rho_X \log X^*_{t-1} + u^*_{X,t}
\end{aligned} \qquad (3.2.20)$$

where the disturbance terms $u_{k,t}$ are normally distributed.

3.2.7 Monetary policy

To close the model we need to specify monetary policy at both the home and the world economies. We assume that all (symmetric) foreign economies share common currency and that monetary policy in this currency union is conducted in an optimal way with commitment. Since the home economy is of measure zero, its policy decisions have no effect on the world economy. The world economy is closed and, given that wages and commodity prices are flexible, targeting the weighted index of tradable and nontradable prices render optimal policy in this economy (see Chapter 6, Section 4.3 in Woodford, 2003; Aoki, 2001). Under assumption that frequencies of price changes and elasticities in tradable and nontradable sectors are equal, $\omega_N = \omega_T$ and $\eta_N = \eta_T$, this weighted index coincides with the core consumer price index, i.e. consumer price index without commodity component.

I consider four alternative monetary policy regimes for small commodity-exporting economy. The first is credible *fixed nominal exchange rate* regime (FER):

$$\Delta e_t = \log\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right) = 0, \forall t \tag{3.2.21}$$

where $\mathcal{E}_t$ is the nominal exchange rate of the home currency.

The second regime is strict *core CPI inflation targeting* (CIT):

$$\pi_{B,t} = \log\left(\frac{P_{B,t}}{P_{B,t-1}}\right) = 0, \forall t \tag{3.2.22}$$

where $P_{B,t} = \left(\frac{\alpha_N}{\alpha_N+\alpha_T}P_{N,t}^{1-\epsilon} + \frac{\alpha_T}{\alpha_N+\alpha_T}P_{T,t}^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$ is core consumer price index.

The third regime is strict *non-commodity domestic output inflation targeting* (DIT):

$$\pi_{D,t} = \log\left(\frac{P_{D,t}}{P_{D,t-1}}\right) = 0, \forall t \tag{3.2.23}$$

where $\pi_{D,t} = \frac{Y_{D,t}^n}{Y_{D,t}}$ is the GDP deflator in tradable and nontradable sectors with $Y_{D,t}^n$ and $Y_{D,t}$ denoting, respectively, nominal and real GDP in these sectors.

Lastly, to characterize an *optimal monetary policy* with commitment (OP) for home economy we need to formulate an infinite-horizon Lagrangian problem where central bank maximizes conditional expected social welfare function:

$$\mathcal{W}_{t_0} = E_{t_0}\sum_{t=t_0}^{\infty}\beta^t\left(\frac{C_t^{1-\sigma}}{1-\sigma} - \chi_N^{-\nu}\frac{L_{N,t}^{1+\nu}}{1+\nu} - \chi_T^{-\nu}\frac{L_{T,t}^{1+\nu}}{1+\nu}\right) \tag{3.2.24}$$

subject to the full set of equilibrium conditions for home and foreign economies for all $t \geq t_0$ (implementability constraints) and precommitment constraints for forward-looking variables at $t = t_0$.[12] Note, that optimal policy is conducted in non-cooperative way. Hence, monetary authority, having monopolistic power over domestic terms of trade, may affect them in a beneficial way for the home economy (see in particular Corsetti and Pesenti, 2001; Benigno and Benigno, 2003).

Appendix C.1 summarizes equilibrium conditions for the previous model of small commodity-exporting economy/the world economy. Below, basic simulation results and welfare evaluations under the four above-mentioned monetary policy regimes are provided for a calibrated version of the model. Yet, before moving to the results, a brief discussion

[12]We consider here optimal policy from the timeless perspective, as e.g. in Woodford (2010) or Levin, Onatski, Williams, and Williams (2006).

of the model calibration strategy is in order.

3.3 Calibration

This section presents a calibration of the parameters and stochastic shocks for the proposed model of a small commodity-exporting economy. The model is calibrated to quarterly data. Most parameters are standard and their values are taken from the literature. The benchmark calibration is summarized in Table C.2.

We set the quarterly discount factor β equal to 0.99, which implies an annual steady-state real interest rate of about 4%. The inverse of the intertemporal elasticity of substitution, σ, is fixed at 2 as in most of the literature.[13] The parameter ν plays dual role in our model: on the one hand, its inverse determines the Frisch elasticity of labor supply and, on the other, the elasticity of substitution of labor supply across tradable and nontradable firms. The value of the Frish elasticity is ambiguous, as stressed by Christiano, Eichenbaum, and Evans (1997). In most of the microeconomic studies its estimate is very small, often close to 0. By contrast, the real business cycles literature typically work with labor supply elasticities of much higher magnitude, sometimes in excess of 5. Given this wide the range, following Christiano et al. (1997), I use a benchmark value for ν, equal to 1, which also corresponds to an estimate of cross-sectoral elasticity of substitution of labor given by Horvath (2000) and Kim and Kim (2006).

The elasticity of substitution between tradables, nontradables and commodity, ϵ, is set to 0.74 as in Mendoza (1991). There is some controversy about the value of trade elasticity θ (see for example Ruhl (2004) for a good review). The elasticities considered in the international real business cycles literature range from 0.5 to 2.0.[14] I use value 1.5 as in Backus et al. (1992). The elasticities of substitution between varieties in tradable and nontradable sectors, η_T and η_N, are set to 11, what corresponds to price markups equal to 10%. Parameters ω_N and ω_T are set equal to 0.75, a value consistent with an average period of one year between price adjustments (as in Gali and Monacelli, 2005).

The consumption weights of tradable and nontradable goods, α_T and α_N, are set to 0.4 and 0.5 respectively, what corresponds roughly to non-energy goods and services in the consumer price index for Canada. The home weight in consumption of tradable goods, α_H, is equal to 0.5 (according to input-output data for Canada).

The steady-state productivity levels in tradable and nontradable sectors are assumed to be the same for home and foreign economies: $\bar{A}_N = \bar{A}_N^* = \bar{A}_T = \bar{A}_T^* = 1$. Commodity endowment in the world economy, $\bar{X}^*$, is set at 1 too. At the same time, three alternative specifications for the home commodity sector are assumed. The first case, $\bar{X} = 1$, corresponds to ex-ante symmetric home economy. In this case there are no international trade

[13] See for example Backus et al. (1992)

[14] The trade literature works with much higher elasticities in range from 10 to 15.

in primary commodities in deterministic steady state. The second alternative, $\bar{X} = 4$, correspond to the chosen benchmark parametrization of a small commodity-exporting economy. Finally, a model with large home commodity sector: $\bar{X} = 10$ is considered.

To study the effect of financial frictions and international risk sharing, three variants of the model are reported: (i) frictionless asset markets, $\psi = 0$; (ii) an intermediate (benchmark) case with $\psi = 1$, and (iii) financial autarky with $\psi \to \infty$. I also consider two alternative pricing regime for home and foreign tradable firms: producer currency pricing, $\gamma = 1$, and local currency pricing, $\gamma = 0$.

Finally, regarding the parameterization of the exogenous stochastic processes, the persistence parameter, ρ_k, is set equal to 0.8 for all productivity and commodity shocks. At the same time, volatilities of nontradable, tradable and commodity shocks are set to 0.01, 0.02 and 0.04 respectively (both for home and foreign economies). This corresponds roughly to ratio for OECD countries (see Table C.1). Productivity and commodity shocks are assumed to be uncorrelated across countries and sectors.

3.4 Simulation results

3.4.1 Deterministic steady-state equilibrium

It is convenient to start the discussion of the simulation results with a brief look at the deterministic steady-state equilibrium. Given the cross-country asymmetry of the model, this equilibrium allows us to identify long-run structural differences between the home and world economies. It is assumed that, in steady state, both economies have balanced trade and zero inflation.[15] As a result, the corresponding equilibrium depends neither on financial transaction costs ψ, nor on monetary policy regime nor on currency of pricing for tradable goods γ.

A steady-state solution of the model is presented in Table C.3 under the three alternative assumptions about the steady-state home commodity endowment $\bar{X}$. First, we consider a symmetric case, $\bar{X} = 1$, where home economy is identical to typical foreign economy. Then we introduce two variants of the commodity-abundant home economy: $\bar{X} = 4$ and $\bar{X} = 10$.

As expected, deterministic steady-state allocations and prices in home and foreign economies coincide in a symmetric case. There is no international trade in commodity, whereas home export and import are driven by intra-industry trade in (non-commodity) tradable goods. Besides, the steady-state real exchange rate (i.e., the inverse of the international price level) is equal to one.

[15] An optimal steady state exists in which the inflation rate is zero in our model with optimal monetary policy. We checked it by conjecturing that the solution involves zero inflation, and then determining that augmented matrix of the system of N equations for $N-1$ Lagrange multipliers has rank equal to $N-1$.

In contrast, the model with commodity-abundant home economy generates important asymmetries in the steady state. First, higher commodity endowment makes the home economy wealthier than the foreign one. Households in the home economy enjoy higher welfare, consume more nontradable, tradable and commodity goods (both in aggregate terms and separately in each type of good), and also work less.

Second, international trade flows fit well with a law of comparative advantages: the home country exports primary commodity whereas its imports of foreign tradable goods exceed the exports of home tradables. Notice that this steady-state trade pattern captures an important source of business cycle fluctuations for the small commodity-exporting economy, since world commodity price changes may induce significant windfall incomes (or losses) from commodity export.

Third, higher demand in home economy pushes up wages and prices of nontradable and home tradable goods. At the same time, relative domestic prices of foreign tradable goods and commodity fall. As a result, home consumption of foreign tradable goods increases, whereas foreign consumption of home tradable goods falls. However, income and substitution effects work in opposite direction for home demand on home tradable goods. In the case of $\bar{X} = 4$, the income effect dominates in steady state, so that home consumption of its own tradables increases relative to the symmetric variant of the model. Conversely, the substitution effect dominates in the case of large commodity sector, $\bar{X} = 10$. Nevertheless, total demand (home and foreign) on home tradable goods unambiguously decreases. Thus, output and labor in the home economy shifts from tradable to nontradable sector, reproducing the main feature of the so-called Dutch disease.

Lastly, high relative prices of home nontradable and tradable goods result in a higher international price level for the home economy relative to the foreign one (i.e, the steady-state real exchange rate is now lower than 1).

3.4.2 Impulse responses

In this section, I illustrate the dynamic effects of the foreign commodity shocks on a number of home macroeconomic variables. I focus here on the benchmark model with intermediate financial transaction costs, $\psi = 1$, and average size of the home commodity sector, $\bar{X} = 4$.[16] Figures C.2-C.7 display impulse responses to negative unitary innovation in the foreign commodity endowment under the four monetary policy regimes.

A decrease in the foreign commodity endowment results in higher world real commodity price. Besides, the size of the price increase exceeds the size of initial commodity shock, since the demand for commodity is inelastic (elasticity of substitution between commodity and non-commodity goods ϵ in our model is less than 1. Both foreign output and consumption fall due to the immediate decrease in commodity supply and to the induced

[16] The model is solved in Dynare package for MATLAB. The first-order necessary conditions for optimal policy are computed using Andrew T. Levin's code (Levin et al., 2006).

reduction in the demand on nontradable and tradable goods. Since the foreign central bank targets non-commodity consumer price inflation, core inflation does not change. At the same time headline inflation rises following the rise in the price of its commodity component.

Given that home economy is a net exporter of commodity in the deterministic steady state, the rise of the world commodity price leads to increase in home trade balance. Non-zero financial transaction costs hinder international risk sharing between home and foreign households, so that windfall income from commodity exports is partly spent inside of home economy. As a result, the real exchange rate appreciates whereas demand shifts from commodity and home tradable goods to foreign tradable and home nontradable goods, and labor switches from home tradable to nontradable firms.

Since the prices of tradable and nontradable goods are sticky in the short run, monetary policy can manipulate real exchange rate (and therefore home and foreign demands) to some extent. Under the producer currency pricing (PCP) regime, the nominal exchange rate changes imply a full pass-through to import prices and therefore play a expenditure-switching role. A central bank that targets core consumer inflation allows the nominal exchange rate to float freely, absorbing the change in the real exchange rate. Domestic non-commodity output inflation targeting and optimal policy have similar effects.[17] By contrast, in the case of fixed nominal exchange rate (and stable foreign consumer prices), the real exchange rate may appreciate only slowly through consumer inflation in the home economy. Hence, the real exchange rate appreciation is restrained but at the cost of higher inflation. In other words, monetary policy is too loose in this case, and so consumption and output in the home economy are higher than under flexible exchange rate regimes.

Under the local currency pricing (LCP) regime, the dynamic effects of an increase in commodity prices on the home economy is similar. But, since in this case the nominal exchange rate pass-through is zero, the expenditure-switching effect of the nominal exchange rate is hindered. Since an adjustment of the trade balance through changes in relative prices is sluggish, the nominal exchange rate has to appreciate even more than under PCP to comply with the international risk-sharing condition C.1.14. Given that home tradable firms set their prices in local currency, the nominal appreciation results in higher prices of home tradable goods for the domestic market than for the foreign market. Thus, in contrast to PCP case, the law of one price for these goods fails. At the same time, the relative price of nontradable vs. tradable consumption goods and the relative price of home vs. foreign tradable consumption goods raise less strongly than in the PCP case, due to the home currency pricing of the import goods.

[17] Since consumer price index includes imported consumer goods and under PCP their prices are correlated with nominal exchange rate, core consumer inflation targeting places higher weight on stabilizing nominal exchange rate than other flexible regimes.

3.4.3 Business cycles statistics

This section is devoted to a brief discussion of the business-cycle properties of some relevant macroeconomic variables under the four monetary policy regimes. I focus on two business cycles moments: standard deviations and contemporary correlations with the real foreign commodity price. These statistics are reported for models with different values of the financial transaction costs parameter, ranging from perfect international risk sharing, $\psi = 0$, to financial autarky, $\psi \to \infty$.[18] Table C.4 and Figure C.8 display these business-cycle statistics generated by foreign commodity shocks only, whereas Table C.5 and Figure C.9 illustrate the results for all productivity and commodity shocks.

In the case of perfect international risk sharing, $\psi = 0$, the foreign commodity shocks can be perfectly insured. Hence, volatility of the real exchange rate induced by these shocks is close to zero and, as result, standard deviations of the core consumer inflation, non-commodity domestic inflation and rate of change of the nominal exchange rate are always small independently of monetary policy regime under consideration. The headline consumer inflation volatility is determined exclusively by the growth rate of the price of its commodity component.

Introduction of the financial frictions results in reduced volatility of the trade balance, increased volatility of the real exchange rate and a negative correlation of the latter with the real commodity price (commodity currency effect). Under a flexible nominal exchange rate regime, obviously it translates into higher volatility of the nominal exchange rate. By contrast, a currency peg implies higher volatility of inflation as well as its positive correlation with the real commodity price. At the same time, the real exchange rate is not surprisingly smoother under a fixed regime, reflecting short-run price stickiness. This effect increases with rising financial costs.

Core consumer inflation targeting regime implies lower volatility of the nominal exchange rate relative to domestic inflation targeting and optimal monetary policy. This result can be explained by the inclusion of import prices in the CPI, and a full pass-through of the nominal exchange rate changes into those prices under PCP pricing.

Introduction of the other shocks does not alter the results significantly. The only important difference is the non-zero volatility of the real exchange rate in the case of null financial transaction costs, reflecting the impossibility of getting insurance against shocks in the nontradable sector as well as the home bias in consumption of tradable goods. Nevertheless, rising financial transaction costs increase real exchange rate volatility and its negative correlation with real commodity price: as in the previous case this implies a trade-off between stability of nominal exchange rate and inflation.

[18] For brevity, only the case of PCP pricing is presented here.

3.5 Welfare analysis

This section reports the main results of the chapter. We evaluate welfare implications of the fixed and flexible exchange rate regimes under alternative specifications of the model of small commodity-exporting economy. This welfare analysis focusess on three key parameters.

First, I compare welfare costs of the exchange rate regimes under three different assumptions about the extent of international risk sharing (perfect international risk sharing, $\psi = 0$, financial autarky, $\psi \to \infty$, and an intermediate case, $\psi = 1$). Second, I analyze the welfare implications of the different size of the home commodity sector. The first case is the one where home and foreign economies are completely symmetric ex ante: $\bar{X} = \bar{X}^* = 1$. Then, I consider two variants of the commodity abundant small home economy: $\bar{X} = 4$ and $\bar{X} = 10$. Finally, I report the results for two variants of the pricing regime of the tradable firms: producer currency pricing, $\gamma = 1$, and local currency pricing, $\gamma = 0$.

As before, the above-mentioned four monetary policy regimes are considered (credible peg of the nominal exchange rate, targeting the core consumer inflation, targeting the domestic output inflation and optimal policy with commitment). Results are reported under two scenarios. The first one assumes that the only shock affecting the model economy is a foreign commodity shock. Under the second scenario, the model is affected by the full set of home and foreign productivity and commodity shocks.

To evaluate the welfare costs of the alternative monetary policy regimes, second-order approximations of the welfare and policy functions are used (see Schmitt-Grohe and Uribe, 2004). Notice that a standard welfare analysis of the model of open economy using second-order approximation to the welfare function but just a linear approximation to policy function may provide spurious results. For example, Kim and Kim (2003) show that in a simple two-agent economy, this standard method may yield higher welfare under financial autarky than under perfect risk sharing. The problem is that some key second-order terms of the equilibrium welfare function are omitted. Consequently, the resulting criterion becomes inaccurate to order two.

3.5.1 Welfare metrics

I now describe the welfare metric used to evaluate exchange rate regimes. I adopt a procedure proposed by Lucas (1991). More specifically, the unconditional welfare loss is measured in terms of the fraction, ξ, of additional deterministic steady-state consumption needed to equate the unconditional expected utility under uncertainty with the utility obtained under the deterministic steady state:

$$U((1+\xi)\bar{C}, \bar{L}_N, \bar{L}_T) = E\big\{U(C_t, L_{N,t}, L_{T,t})\big\} \tag{3.5.1}$$

After taking a second-order approximation of the welfare function, expected utility can be rewritten as:

$$\begin{aligned} E\{U(C_t, L_{N,t}, L_{T,t})\} &\approx U(\bar{C}, \bar{L}_N, \bar{L}_T) + \bar{C}^{1-\sigma}E\{\hat{C}_t\} + \frac{1-\sigma}{2}\bar{C}^{1-\sigma}Var\{\hat{C}_t\}- \\ &- \chi_N^{-\nu}\bar{L}_N^{1+\nu}E\{\hat{L}_{N,t}\} - \chi_N^{-\nu}\frac{1+\nu}{2}\bar{L}_N^{1+\nu}Var\{\hat{L}_{N,t}\}- \\ &- \chi_T^{-\nu}\bar{L}_T^{1+\nu}E\{\hat{L}_{T,t}\} - \chi_T^{-\nu}\frac{1+\nu}{2}\bar{L}_T^{1+\nu}Var\{\hat{L}_{T,t}\} \end{aligned} \tag{3.5.2}$$

where $\hat{C}_t$, $\hat{L}_{N,t}$ and $\hat{L}_{T,t}$ denote (log)deviations of the variables from the deterministic steady state.

Then, the welfare metric, ξ, is computed as:

$$\xi = \Big((1+\xi^m)^{1-\sigma} + (1+\xi^v)^{1-\sigma} - 1\Big)^{\frac{1}{1-\sigma}} - 1 \tag{3.5.3}$$

where ξ^v and ξ^m denote the parts of welfare costs respectively due to the variance of uncertain consumption and leisure, as well as to the effect of uncertainty on the means of these variables (see Kollmann, 2002). These parameters are determined as:

$$\begin{aligned} \xi^m &= \Big(1 + (1-\sigma)E\{\hat{C}_t\} - (1-\sigma)\frac{\chi_N^{-\nu}\bar{L}_N^{1+\nu}}{\bar{C}^{1-\sigma}}E\{\hat{L}_{N,t}\} - (1-\sigma)\frac{\chi_T^{-\nu}\bar{L}_T^{1+\nu}}{\bar{C}^{1-\sigma}}E\{\hat{L}_{T,t}\}\Big)^{\frac{1}{1-\sigma}} - 1 \\ \xi^v &= \Big(1 + \frac{(1-\sigma)^2}{2}Var\{\hat{C}_t\} - \frac{(1-\sigma)(1+\nu)}{2}\frac{\chi_N^{-\nu}\bar{L}_N^{1+\nu}}{\bar{C}^{1-\sigma}}Var\{\hat{L}_{N,t}\}- \\ &- \frac{(1-\sigma)(1+\nu)}{2}\frac{\chi_T^{-\nu}\bar{L}_T^{1+\nu}}{\bar{C}^{1-\sigma}}Var\{\hat{L}_{T,t}\}\Big)^{\frac{1}{1-\sigma}} - 1 \end{aligned}$$

We compute the welfare losses ξ for alternative monetary policy regimes as well as for a *natural* equilibrium of the model, $\tilde{\xi}$. This natural equilibrium assumes that prices are flexible in the home economy whereas they are sticky in the foreign economy. Thus, equilibrium of the world economy is the same both in the sticky and flexible variants of the model. In what follows, I report welfare losses in terms of the steady-state consumption comparing to the natural equilibrium: $\xi - \tilde{\xi}$.

3.5.2 Welfare evaluations: the foreign commodity shock

Table C.6 summarizes our welfare evaluations under an assumption that the only shock in the model is the foreign commodity shock. This variant of the model deserves a special consideration, given that foreign commodity shocks are the key determinant of the commodity price volatility in our model.[19]

[19] Since deterministic steady-state equilibrium changes with the size of home commodity sector, welfare losses are not directly comparable for models with different values of $\bar{X}$. So, for example, one percent loss for the model with $\bar{X} = 4$ is smaller in absolute terms than one percent loss for the model with $\bar{X} = 10$.

I start discussing the symmetric case: $\bar{X} = \bar{X}^* = 1$. The simulations show that welfare losses in this variant of the model are negligible irrespectively of the monetary policy regime, the extent of international risk-sharing or the currency of pricing. The commodity price hike after negative foreign commodity shock in this case does not induce significant windfall income from commodity export; so, even in financial autarky, the real exchange rate appreciates very slightly. As a result, there is no need to change significantly neither the rigid nominal prices nor the flexible nominal exchange rate regime. In other words, the choice of the monetary policy regime does not matter in this variant of the model.

The picture, however, changes significantly for a commodity-abundant small economy. In this case, windfall income from commodity exports is not trivial, and the way in which this income is spent has significant implications on the real exchange rate volatility. Under an assumption of frictionless asset markets, $\psi = 0$, the foreign commodity shock is perfectly shared between the home and foreign economies without any effect on home real exchange rate. Hence, as in a symmetric case, there is no difference in terms of welfare about which monetary policy regime to apply. On the other hand, introduction of financial intermediation costs makes suboptimal to insure completely against foreign commodity shocks and so windfall income from commodity exports is spent partly inside of home economy leading to an appreciation of the real exchange rate. In this case, a choice of the monetary policy regime has important welfare implications. Given that nominal prices are rigid and inflation is very costly, the flexible exchange rate regimes are preferable to nominal peg. For example, in the case of intermediate size of home commodity sector, $\bar{X} = 4$, and producer currency pricing regime, $\gamma = 1$, the model of financial autarky generates welfare loss of 0,21% of the steady-state consumption under nominal exchange rate peg compared to a loss of 0,03% under consumer inflation targeting and 0,02% under domestic inflation targeting or optimal policy.

A larger size of home commodity sector may significantly increase the welfare costs associated to the fixed nominal exchange rate regime. So, under an assumption that $\bar{X} = 10$ the model of financial autarky generates loss 2,94% of the steady-state consumption for the fixed nominal exchange rate comparied to 0,57% funder CPI targeting, 0,07% under domestic inflation targeting and 0,02% under optimal monetary policy.[20] These high welfare costs reflect the increased volatility of the real exchange rate, and as a result a larger volatility of inflation under the fixed nominal exchange rate regime. The model with intermediate financial costs, $\psi = 1$, generates a welfare loss of 1,2% for the nominal peg against 0,16% under CPI targeting and 0,01% under either domestic inflation targeting or optimal policy. However, for the model with perfect capital markets, $\psi = 0$, welfare

[20]Given that deterministic steady-state consumption in the model with $\bar{X} = 10$ is higher than in the model with $\bar{X} = 4$, relatively higher welfare losses in the first case correspond to even higher losses in absolute terms.

costs are negligible irrespectively of the chosen monetary policy regime and the size of the home commodity sector.

The model with local currency pricing, $\gamma = 0$, does not change the welfare rankings for the fixed nominal exchange rate regime. As before, frictionless financial markets ensure low volatility of the real exchange rate and very small welfare costs of the nominal peg. In contrast, the model with financial frictions and large home commodity sector yields high welfare losses for this regime. In fact, for a credible fixed exchange rate regime, the currency of pricing does not matter and the only difference between these two pricing regimes is that under LCP home and foreign markets are segmented, whereas under PCP the price is the same for both markets.[21]

However, a choice of the currency of pricing has nontrivial implications for flexible nominal exchange rate regimes. First, local currency pricing contains an additional source of inefficiency due to the deviations from the law of one price for prices set to domestic and foreign markets, which lead to distortions in the supply of tradable goods. The volatile nominal exchange rate reveals this inefficiency by generating higher welfare costs of the optimal policy compared to the model with PCP. For example, the model of financial autarky with $\bar{X} = 10$ yields welfare loss of 0,27% for optimal policy under LCP versus loss of 0,02% under PCP.

Second, a choice of the currency of pricing may even change a welfare ranking of the two other flexible nominal exchange rate regimes (targeting core consumer inflation and targeting non-commodity domestic inflation). So, for example, in the model of financial autarky with $\bar{X} = 10$, core CPI targeting and domestic inflation targeting regimes have respectively welfare losses 0,57% and 0,07% under PCP, and 0,27% and 0,33% under LCP.

Regarding this last result, it is interesting to highlight that targeting core consumer inflation yields smaller welfare costs under LCP despite an additional source of inefficiency in this model. To explain this fact, it is convenient to recall that core CPI index in our model includes nontradable goods, a fraction of home tradable goods and foreign tradable goods. In the model of financial autarky, a negative foreign commodity shock results in real exchange rate appreciation and, under core consumer inflation targeting, in nominal exchange rate appreciation. The nominal exchange rate fluctuations exhibit full pass-trough into import prices under the PCP regime. Therefore, since prices of imported goods fall significantly, the monetary authority targeting core CPI inflation needs to tolerate an increase in prices of home tradable and nontradable goods. As a result, domestic inflation has a distortionary effect on output and generates high welfare losses for this regime of monetary policy. By contrast, under LCP, the nominal exchange rate pass-through is zero. Therefore, the import prices do not fall significantly after nominal appreciation and there is no need to tolerate higher domestic inflation.

[21] The pricing to market has only second-order effect on price decisions.

3.5.3 Welfare evaluations: all shocks

I now consider welfare evaluations for the model affected by the full set of home and foreign productivity and endowment shocks. Table C.7 reports the main results. Though welfare costs in this scenario are higher, the main conclusions are virtually the same as before.

First, the extent of international risk sharing and the size of home commodity sector are key factors determining the welfare costs of the fixed nominal exchange rate regime. Though the nominal peg yields higher welfare losses compared to flexible exchange rate regimes for all combination of parameters, these costs are small under frictionless asset markets, $\psi = 0$, or for the model with small commodity sector, $\bar{X} = 1$. In contrast, the model of financial autarky with $\bar{X} = 10$ generates huge welfare loss of 4,8% in terms of the steady-state consumption.

Second, the choice of the currency of pricing has no significant welfare effects for the fixed regime of the nominal exchange rate. Further, targeting core consumer inflation is performs worse than targeting non-commodity domestic inflation under PCP, but the ranking of these two regimes changes under LCP.

3.6 Conclusions

In this chapter, I have investigated the welfare implications of the fixed and flexible exchange rate regimes in a model of a small commodity-exporting economy. I explicitly model the world economy, which allows us to control directly for the extent of international risk-sharing. The model is solved numerically using a second-order approximation to welfare and policy functions in order to correctly uncover the relationship between uncertainty and welfare. The results confirm that, in general, flexible exchange rate regimes have better welfare properties than the nominal peg. However, the welfare costs of the fixed nominal exchange rate vary significantly with the extent of international risk sharing and size of the home commodity endowment.

I also study alternative flexible nominal exchange rate regimes and compare their welfare properties to those under an optimal monetary policy under commitment. In particular, I find that the currency of pricing for imported goods may have important welfare consequences for two targeting regimes: the core consumer inflation targeting and non-commodity domestic inflation targeting. Under the chosen parameterization, the second regime is preferable to the first one in the case of producer currency pricing, whereas the ranking switches under local currency pricing.

In line with the available literature on this topic, our results emphasize the importance of adopting some kind of cross-country risk sharing mechanisms for a small commodity-exporting economy. In the absence of this type of mechanisms, the welfare costs of uninsured commodity price shocks may be very large for this kind of economies. In practice, cross-country risk sharing may be achieved by hedging in commodity futures markets, creating some form of stabilization fund or even participating in a full-fledged fiscal union.

Appendix C

Appendices to Chapter 3

C.1 Equilibrium

In this appendix we discuss an equilibrium of the model of a small commodity-exporting economy.

C.1.1 Foreign economy

An equilibrium of the typical foreign economy (world economy) is given here. This equilibrium is not affected by the allocations, prices and policies in the home economy since the latter has zero measure.

An optimal choice of the foreign households as well as their null assets holdings imply that the stochastic discount factors are equal to the intertemporal marginal rates of substitution in consumption:

$$\mathcal{Q}^*_{t,t+1} = \mathcal{F}^*_{t,t+1} = \beta \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\sigma} \frac{P^*_t}{P^*_{t+1}} \tag{C.1.1}$$

The foreign nominal risk-free interest rate is determined then by:

$$\frac{1}{1+i^*_t} = E_t \mathcal{Q}^*_{t,t+1} = \beta E_t \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\sigma} \frac{P^*_t}{P^*_{t+1}} \tag{C.1.2}$$

The consumption-labor choice of the foreign households implies:

$$\frac{W^*_{N,t}}{P^*_t} = C^{*\sigma}_t \left(\frac{L^*_{N,t}}{\chi^*_N} \right)^{\nu}, \quad \frac{W^*_{T,t}}{P^*_t} = C^{*\sigma}_t \left(\frac{L^*_{T,t}}{\chi^*_T} \right)^{\nu} \tag{C.1.3}$$

The consumer demand on nontradable, tradable goods and commodity is given by:

$$C^*_{N,t} = \alpha_N \left(\frac{P^*_{N,t}}{P^*_t} \right)^{-\epsilon} C^*_t, \quad C^*_{T,t} = \alpha_T \left(\frac{P^*_{T,t}}{P^*_t} \right)^{-\epsilon} C^*_t, \quad C^*_{X,t} = \alpha_X \left(\frac{P^*_{X,t}}{P^*_t} \right)^{-\epsilon} C^*_t \tag{C.1.4}$$

The foreign headline (including commodity goods) and core (without commodity goods) consumer price indices are determined by:

$$P^{*1-\epsilon}_t = \alpha_N P^{*1-\epsilon}_{N,t} + \alpha_T P^{*1-\epsilon}_{T,t} + \alpha_X P^{*1-\epsilon}_{X,t}, \quad P^{*1-\epsilon}_{B,t} = \frac{\alpha_N}{\alpha_N + \alpha_T} P^{*1-\epsilon}_{N,t} + \frac{\alpha_T}{\alpha_N + \alpha_T} P^{*1-\epsilon}_{T,t} \tag{C.1.5}$$

Aggregation of the production functions in nontradable and tradable sectors results in:

$$\mathcal{R}^*_{N,t}Y^*_{N,t} = A^*_{N,t}L^*_{N,t}, \quad \mathcal{R}^*_{T,t}Y^*_{T,t} = A^*_{T,t}L^*_{T,t} \tag{C.1.6}$$

where $\mathcal{R}^*_{N,t}$ and $\mathcal{R}^*_{T,t}$ are inefficiency terms reflecting distortions in allocation of labor caused by variations in sector prices. These terms satisfy for $j \in \{N, T\}$:

$$\mathcal{R}^*_{j,t} = (1-\omega_j)\left(\frac{\mathcal{P}^*_{j,t}}{P^*_{j,t}}\right)^{-\eta_j} + \omega_j\left(\frac{P^*_{j,t-1}}{P^*_{j,t}}\right)^{-\eta_j}\mathcal{R}^*_{j,t-1} \tag{C.1.7}$$

Pricing decisions of the foreign firms $j \in \{N, T\}$ imply:

$$\begin{aligned} &P^{*1-\eta_j}_{j,t} = \omega_j P^{*1-\eta_j}_{j,t-1} + (1-\omega_j)\mathcal{P}^{*1-\eta_j}_{j,t}, \quad \mathcal{P}^*_{j,t}\mathcal{A}^*_{j,t} = \mathcal{B}^*_{j,t} \\ &\mathcal{A}^*_{j,t} = \frac{Y^*_{j,t}}{P^{*-\eta_j}_{j,t}} + \omega_j E_t\mathcal{F}^*_{t,t+1}\mathcal{A}^*_{j,t+1}, \quad \mathcal{B}^*_{j,t} = (1-s_j)\frac{\eta_j}{\eta_j-1}\frac{Y^*_{j,t}}{P^{*-\eta_j}_{j,t}}\frac{W^*_{j,t}}{A^*_{j,t}} + \omega_j E_t\mathcal{F}^*_{t,t+1}\mathcal{B}^*_{j,t+1} \end{aligned} \tag{C.1.8}$$

Market clearing conditions:

$$C^*_{N,t} = Y^*_{N,t}, \quad C^*_{T,t} = Y^*_{T,t}, \quad C^*_{X,t} = X^*_t \tag{C.1.9}$$

Finally, foreign monetary policy is determined by the core inflation targeting:

$$\pi^*_{B,t} = \log\left(\frac{P^*_{B,t}}{P^*_{B,t-1}}\right) = 0 \tag{C.1.10}$$

This monetary policy rule is optimal for closed world economy given that frequencies of price changes in tradable and nontradable sectors are equal $\omega_N = \omega_T$ and nominal price of commodity is flexible (see Chapter 6, Section 4.3 in Woodford (2003) and Aoki (2001)).

C.1.2 Home economy

An equilibrium in small home economy is given here.

Financial transaction costs create a wedge between the nominal stochastic discount factors and the intertemporal marginal rates of substitution in consumption of home households:

$$\frac{\mathcal{Q}_{t,t+1}}{1 - \frac{P_{N,t+1}}{P_{t+1}}\psi\frac{D_{t+1}}{P_{t+1}}} = \mathcal{F}_{t,t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+1}} \tag{C.1.11}$$

The home nominal risk-free interest rate (gross of transaction costs) is then determined by:

$$\frac{1}{1+i_t} = E_t\mathcal{Q}_{t,t+1} = \beta E_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+1}}\left(1 - \frac{P_{N,t+1}}{P_{t+1}}\psi\frac{D_{t+1}}{P_{t+1}}\right) \tag{C.1.12}$$

The stochastic discount factors for the pay-offs in home and foreign currencies are linked as follows:

$$\mathcal{Q}_{t,t+1} = \mathcal{Q}^*_{t,t+1}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} \tag{C.1.13}$$

As a result of the above relationship, international risk-sharing condition is determined as:

$$\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(1 - \frac{P_{N,t+1}}{P_{t+1}}\psi\frac{D_{t+1}}{P_{t+1}}\right) = \left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{\frac{P^*_t\mathcal{E}_t}{P_t}}{\frac{P^*_{t+1}\mathcal{E}_{t+1}}{P_{t+1}}} \tag{C.1.14}$$

The consumption-labor choice of the home households implies:

$$\frac{W_{N,t}}{P_t} = C_t^{\sigma}\left(\frac{L_{N,t}}{\chi_N}\right)^{\nu}, \quad \frac{W_{T,t}}{P_t} = C_t^{\sigma}\left(\frac{L_{T,t}}{\chi_T}\right)^{\nu} \tag{C.1.15}$$

The consumer demand on nontradable goods, tradable goods and commodity is:

$$C_{N,t} = \alpha_N\left(\frac{P_{N,t}}{P_t}\right)^{-\epsilon} C_t, \;\; C_{T,t} = \alpha_T\left(\frac{P_{T,t}}{P_t}\right)^{-\epsilon} C_t, \;\; C_{X,t} = \alpha_X\left(\frac{P_{X,t}}{P_t}\right)^{-\epsilon} C_t \tag{C.1.16}$$

Headline and core consumer price indices are determined by:

$$P_t^{1-\epsilon} = \alpha_N P_{N,t}^{1-\epsilon} + \alpha_T P_{T,t}^{1-\epsilon} + \alpha_X P_{X,t}^{1-\epsilon}, \;\; P_{B,t}^{1-\epsilon} = \frac{\alpha_N}{\alpha_N+\alpha_T}P_{N,t}^{1-\epsilon} + \frac{\alpha_T}{\alpha_N+\alpha_T}P_{T,t}^{1-\epsilon} \tag{C.1.17}$$

The consumer demand on home and foreign tradable goods as well as price index of tradable goods are given by the following equations:

$$C_{H,t} = \alpha_H\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\theta} C_{T,t}, \;\; C_{F,t} = (1-\alpha_H)\left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\theta} C_{T,t} \tag{C.1.18}$$

$$P_{T,t}^{1-\theta} = \alpha_H P_{H,t}^{1-\theta} + (1-\alpha_H)P_{F,t}^{1-\theta} \tag{C.1.19}$$

Aggregate production functions in nontradable and tradable sectors:

$$\mathcal{R}_{N,t}Y_{N,t} = A_{N,t}L_{N,t}, \;\; \mathcal{R}_{H,t}Y_{H,t} + \left(\gamma\mathcal{R}_{H,t}^{P*} + (1-\gamma)\mathcal{R}_{H,t}^{L*}\right)Y_{H,t}^{*} = A_{T,t}L_{T,t} \tag{C.1.20}$$

where $\mathcal{R}_{N,t}$, $\mathcal{R}_{H,t}$, $\mathcal{R}_{H,t}^{P*}$ and $\mathcal{R}_{H,t}^{L*}$ are inefficiency terms reflecting distortions in allocation of labor caused by variations in sector prices.

These terms satisfy:

$$\begin{aligned}
\mathcal{R}_{N,t} &= (1-\omega_N)\left(\frac{\mathcal{P}_{N,t}}{P_{N,t}}\right)^{-\eta_N} + \omega_N\left(\frac{P_{N,t-1}}{P_{N,t}}\right)^{-\eta_N}\mathcal{R}_{N,t-1}\\
\mathcal{R}_{H,t} &= (1-\omega_T)\gamma\left(\frac{\mathcal{P}_{H,t}^{P}}{P_{H,t}}\right)^{-\eta_T} + (1-\omega_T)(1-\gamma)\left(\frac{\mathcal{P}_{H,t}^{L}}{P_{H,t}}\right)^{-\eta_T} + \omega_T\left(\frac{P_{H,t-1}}{P_{H,t}}\right)^{-\eta_T}\mathcal{R}_{H,t-1}\\
\mathcal{R}_{H,t}^{P*} &= (1-\omega_T)\left(\frac{\mathcal{P}_{H,t}^{P}}{\mathcal{E}_t P_{H,t}^{*}}\right)^{-\eta_T} + \omega_T\left(\frac{\mathcal{E}_{t-1}P_{H,t-1}^{*}}{\mathcal{E}_t P_{H,t}^{*}}\right)^{-\eta_T}\mathcal{R}_{H,t-1}^{P*}\\
\mathcal{R}_{H,t}^{L*} &= (1-\omega_T)\left(\frac{\mathcal{P}_{H,t}^{L*}}{P_{H,t}^{*}}\right)^{-\eta_T} + \omega_T\left(\frac{P_{H,t-1}^{*}}{P_{H,t}^{*}}\right)^{-\eta_T}\mathcal{R}_{H,t-1}^{L*}
\end{aligned} \tag{C.1.21}$$

Pricing decisions of the firms in home nontaradble sector are given by:

$$\begin{aligned}
&P_{N,t}^{1-\eta_N} = \omega_N P_{N,t-1}^{1-\eta_N} + (1-\omega_N)\mathcal{P}_{N,t}^{1-\eta_N}, \;\; \mathcal{P}_{N,t}\mathcal{A}_{N,t} = \mathcal{B}_{N,t}\\
&\mathcal{A}_{N,t} = \frac{Y_{N,t}}{P_{N,t}^{-\eta_N}} + \omega_N E_t\mathcal{F}_{t,t+1}\mathcal{A}_{N,t+1}, \;\; \mathcal{B}_{N,t} = (1-s_N)\frac{\eta_N}{\eta_N-1}\frac{Y_{N,t}}{P_{N,t}^{-\eta_N}}\frac{W_{N,t}}{A_{N,t}} + \omega_N E_t\mathcal{F}_{t,t+1}\mathcal{B}_{N,t+1}
\end{aligned} \tag{C.1.22}$$

Pricing decisions of the home tradable firms setting prices in producer currency (PCP):

$$\begin{aligned} P_{H,t}^{P1-\eta_T} &= \omega_T P_{H,t-1}^{P1-\eta_T} + (1-\omega_T)\mathcal{P}_{H,t}^{P1-\eta_T}, \;\; \mathcal{P}_{H,t}^{P}\mathcal{A}_{H,t}^{P} = \mathcal{B}_{H,t}^{P} \\ \mathcal{A}_{H,t}^{P} &= \frac{Y_{H,t}}{P_{H,t}^{-\eta_T}} + \frac{Y_{H,t}^*}{\left(\mathcal{E}_t P_{H,t}^*\right)^{-\eta_T}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{A}_{H,t+1}^{P} \\ \mathcal{B}_{H,t}^{P} &= (1-s_T)\frac{\eta_T}{\eta_T-1}\left(\frac{Y_{H,t}}{P_{H,t}^{-\eta_T}} + \frac{Y_{H,t}^*}{\left(\mathcal{E}_t P_{H,t}^*\right)^{-\eta_T}}\right)\frac{W_{T,t}}{A_{T,t}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{B}_{H,t+1}^{P} \end{aligned} \tag{C.1.23}$$

Pricing decisions of the home tradable firms setting prices in local currency (LCP) for home market:

$$\begin{aligned} P_{H,t}^{L1-\eta_T} &= \omega_T P_{H,t-1}^{L1-\eta_T} + (1-\omega_T)\mathcal{P}_{H,t}^{L1-\eta_T}, \;\; \mathcal{P}_{H,t}^{L}\mathcal{A}_{H,t}^{L} = \mathcal{B}_{H,t}^{L} \\ \mathcal{A}_{H,t}^{L} &= \frac{Y_{H,t}}{P_{H,t}^{-\eta_T}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{A}_{H,t+1}^{L}, \;\; \mathcal{B}_{H,t}^{L} = (1-s_T)\frac{\eta_T}{\eta_T-1}\frac{Y_{H,t}}{P_{H,t}^{-\eta_T}}\frac{W_{T,t}}{A_{T,t}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{B}_{H,t+1}^{L} \end{aligned} \tag{C.1.24}$$

Pricing decisions of the home tradable firms setting prices in local currency (LCP) for foreign market:

$$\begin{aligned} P_{H,t}^{L*1-\eta_T} &= \omega_T P_{H,t-1}^{L*1-\eta_T} + (1-\omega_T)\mathcal{P}_{H,t}^{L*1-\eta_T}, \;\; \mathcal{P}_{H,t}^{L*}\mathcal{A}_{H,t}^{L*} = \mathcal{B}_{H,t}^{L*} \\ \mathcal{A}_{H,t}^{L*} &= \frac{Y_{H,t}^*}{P_{H,t}^{*-\eta_T}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{A}_{H,t+1}^{L*}, \;\; \mathcal{B}_{H,t}^{L*} = (1-s_T)\frac{\eta_T}{\eta_T-1}\frac{Y_{H,t}^*}{P_{H,t}^{*-\eta_T}}\frac{W_{T,t}}{\mathcal{E}_t A_{T,t}} + \omega_T E_t \mathcal{F}_{t,t+1}\mathcal{B}_{H,t+1}^{L*} \end{aligned} \tag{C.1.25}$$

Pricing decisions of the foreign tradable firms setting prices in local currency (LCP) for home market:

$$\begin{aligned} P_{F,t}^{L1-\eta_T} &= \omega_T P_{F,t-1}^{L1-\eta_T} + (1-\omega_T)\mathcal{P}_{F,t}^{L1-\eta_T}, \;\; \mathcal{P}_{F,t}^{L}\mathcal{A}_{F,t}^{L} = \mathcal{B}_{F,t}^{L} \\ \mathcal{A}_{F,t}^{L} &= \frac{C_{F,t}}{P_{F,t}^{-\eta_T}} + \omega_T E_t \mathcal{F}_{t,t+1}^*\mathcal{A}_{F,t+1}^{L}, \;\; \mathcal{B}_{F,t}^{L} = (1-s_T)\frac{\eta_T}{\eta_T-1}\frac{C_{F,t}}{P_{F,t}^{-\eta_T}}\frac{\mathcal{E}_t W_{T,t}^*}{A_{T,t}^*} + \omega_T E_t \mathcal{F}_{t,t+1}^*\mathcal{B}_{F,t+1}^{L} \end{aligned} \tag{C.1.26}$$

Price indices of home $P_{H,t}$ and foreign $P_{H,t}^*$ consumption of home tradable goods and home consumption of foreign tradable goods $P_{F,t}$ are computed then as:

$$\begin{aligned} P_{H,t}^{1-\eta_T} &= \gamma P_{H,t}^{P1-\eta_T} + (1-\gamma)P_{H,t}^{L1-\eta_T} \\ P_{H,t}^{*1-\eta_T} &= \gamma\left(\frac{P_{H,t}^{P}}{\mathcal{E}_t}\right)^{1-\eta_T} + (1-\gamma)P_{H,t}^{L*1-\eta_T} \\ P_{F,t}^{1-\eta_T} &= \gamma\left(\mathcal{E}_t P_{T,t}^*\right)^{1-\eta_T} + (1-\gamma)P_{F,t}^{L1-\eta_T} \end{aligned} \tag{C.1.27}$$

The law of one price for commodity:

$$P_{X,t} = \mathcal{E}_t P_{X,t}^* \tag{C.1.28}$$

Market clearing conditions:

$$C_{N,t} + \frac{\psi}{2}\left(\frac{D_t}{P_t}\right)^2 = Y_{N,t}, \;\; C_{H,t} = Y_{H,t}, \;\; C_{H,t}^* = Y_{H,t}^* \tag{C.1.29}$$

Foreign demand on home tradable goods is given by:

$$C_{H,t}^* = (1-\alpha_H)\left(\frac{P_{H,t}^*}{P_{T,t}^*}\right)^{-\eta_T} C_{T,t}^* \tag{C.1.30}$$

Trade balance of the home economy:

$$\begin{aligned} TB_t &= \mathcal{E}_t P^*_{H,t} C^*_{H,t} + P_{X,t}(X_t - C_{X,t}) - P_{F,t} C_{F,t} \\ TB_t &= E_t \mathcal{Q}_{t,t+1} D_{t+1} - D_t \end{aligned} \tag{C.1.31}$$

Indices of the nominal home output and nominal home output of non-commodity goods are defined as:

$$\begin{aligned} Y^n_t &= P_{N,t} Y_{N,t} + P_{H,t} Y_{H,t} + \mathcal{E}_t P^*_{H,t} Y^*_{H,t} + P_{X,t} X_t \\ Y^n_{D,t} &= P_{N,t} Y_{N,t} + P_{H,t} Y_{H,t} + \mathcal{E}_t P^*_{H,t} Y^*_{H,t} \end{aligned} \tag{C.1.32}$$

Indices of the real home output and real home output of non-commodity goods are:

$$\begin{aligned} Y_t &= \bar{P}_N Y_{N,t} + \bar{P}_H Y_{H,t} + \bar{\mathcal{E}} \bar{P}^*_H Y^*_{H,t} + \bar{P}_X X_t \\ Y_{D,t} &= \bar{P}_N Y_{N,t} + \bar{P}_H Y_{H,t} + \bar{\mathcal{E}} \bar{P}^*_H Y^*_{H,t} \end{aligned} \tag{C.1.33}$$

where output is measured in deterministic steady-state prices.

Then, implicit price deflators of the total home output and home output of non-commodity goods are given by:

$$P_{Y,t} = \frac{Y^n_t}{Y_t}, \quad P_{D,t} = \frac{Y^n_{D,t}}{Y_{D,t}} \tag{C.1.34}$$

Four monetary policy rules are considered.

fixed exchange rate regime (FER):

$$\Delta e_t = \log\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right) = 0 \tag{C.1.35}$$

core CPI inflation targeting (CIT):

$$\pi_{B,t} = \log\left(\frac{P_{B,t}}{P_{B,t-1}}\right) = 0 \tag{C.1.36}$$

domestic non-commodity output inflation targeting (DIT):

$$\pi_{D,t} = \log\left(\frac{P_{D,t}}{P_{D,t-1}}\right) = 0 \tag{C.1.37}$$

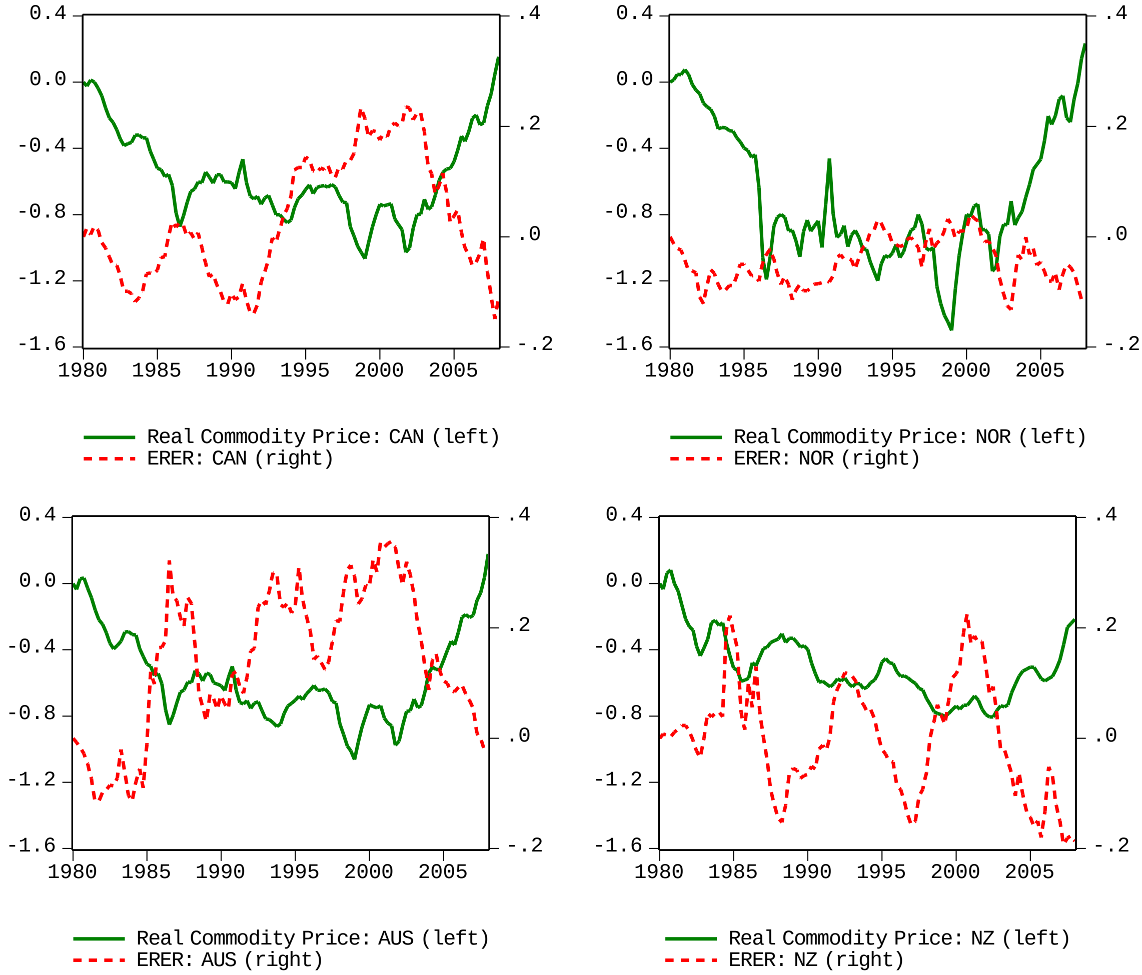
Finally, to compute an *optimal monetary policy with commitment* (OP) for home economy, we need to formulate an infinite-horizon Lagrangian problem where central bank maximizes conditional expected social welfare function:

$$\mathcal{W}_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \chi_N^{-\nu} \frac{L_{N,t}^{1+\nu}}{1+\nu} - \chi_T^{-\nu} \frac{L_{T,t}^{1+\nu}}{1+\nu} \right) \tag{C.1.38}$$

subject to full set of equilibrium conditions for home and foreign economies (C.1.1)-(C.1.31) (see for details Woodford, 2010; Levin et al., 2006).

C.2 Figures

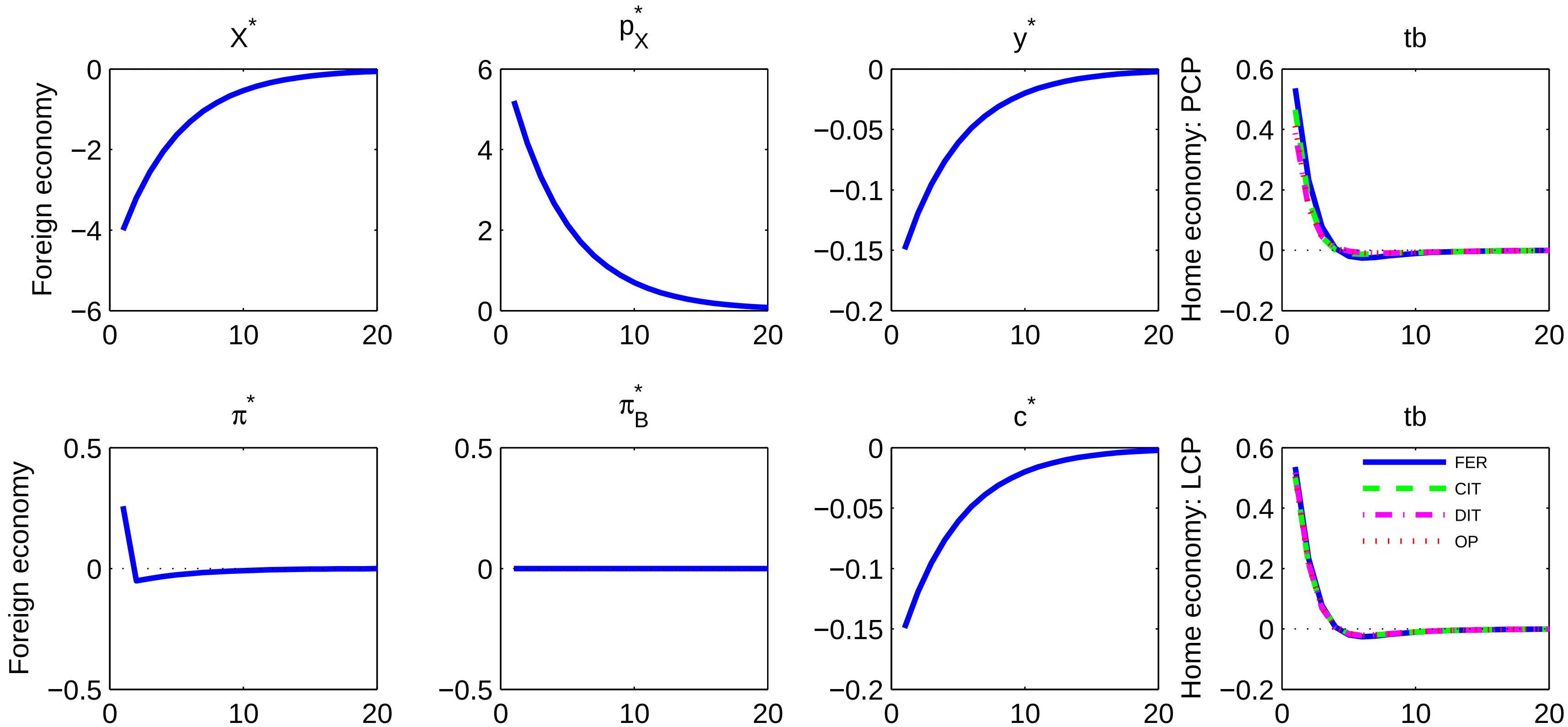
Figure C.1: Commodity currency effect in Canada, Norway, Australia and New Zealand



Sources: OECD EO (export price index of primary commodities in US dollars, CPI in United States), BIS (effective real exchange rates)

Notes: quarterly data in logs for 1980:Q1-2008:Q1, normalized to 1980:Q1

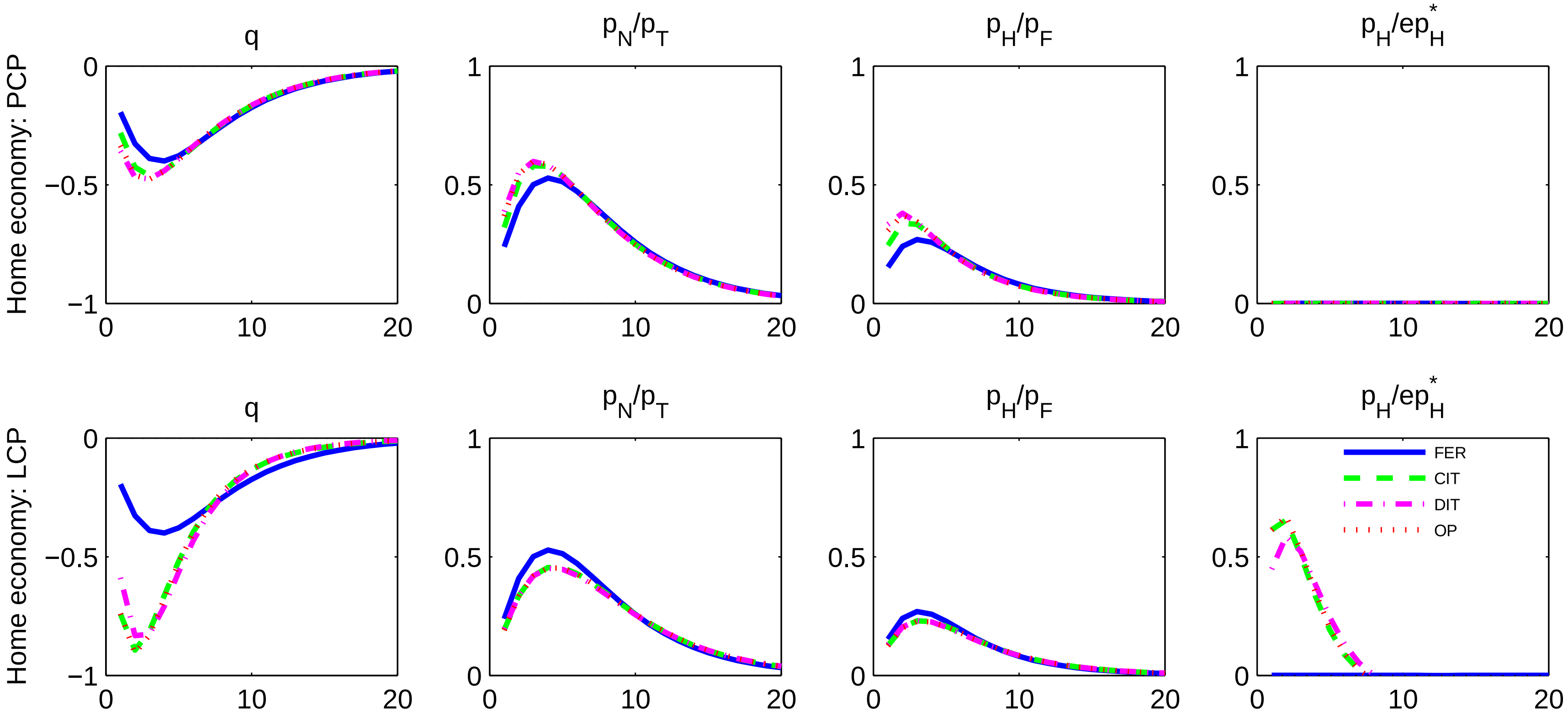
Figure C.2: Impulse responses to foreign commodity shock: foreign economy and home trade balance



FER - fixed exchange rate, CIT - core CPI inflation targeting, DIT - domestic inflation targeting, OP - optimal monetary policy.

X^* - foreign commodity endowment, p_X^* - real foreign commodity price, y^* and c^* - foreign output and consumption, π^* and π_B^* - foreign headline and core CPI inflation, tb - home trade balance (% of home steady-state output).

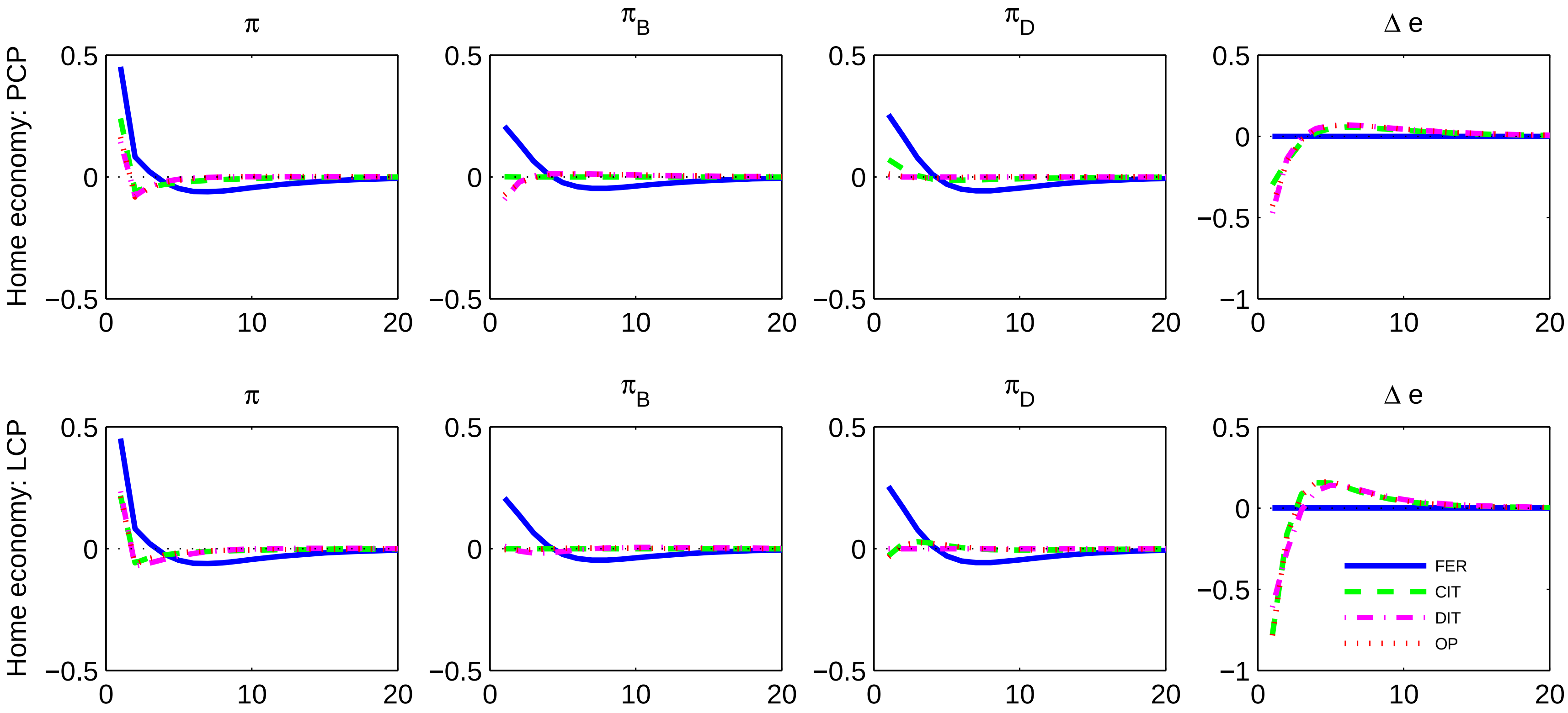
Figure C.3: Impulse responses to foreign commodity shock: home relative prices



---

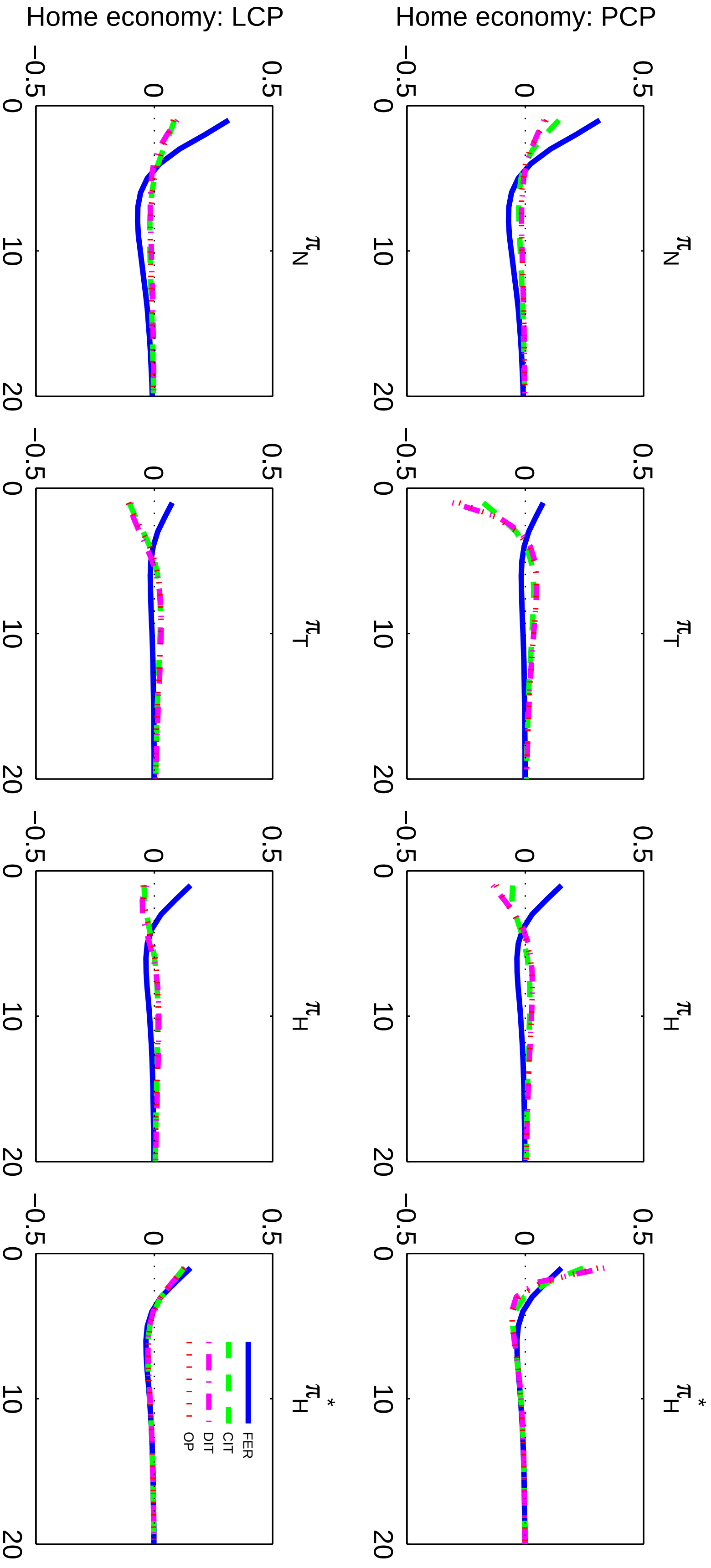
q - real exchange rate, p_N/p_T - price ratio of nontradable and tradable consumption goods, p_H/p_F - price ratio of home and foreign consumption goods, p_H/ep_H^* - price ratio of home tradable goods supplied to home and foreign markets.

Figure C.4: Impulse responses to foreign commodity shock: home inflation and nominal exchange rate



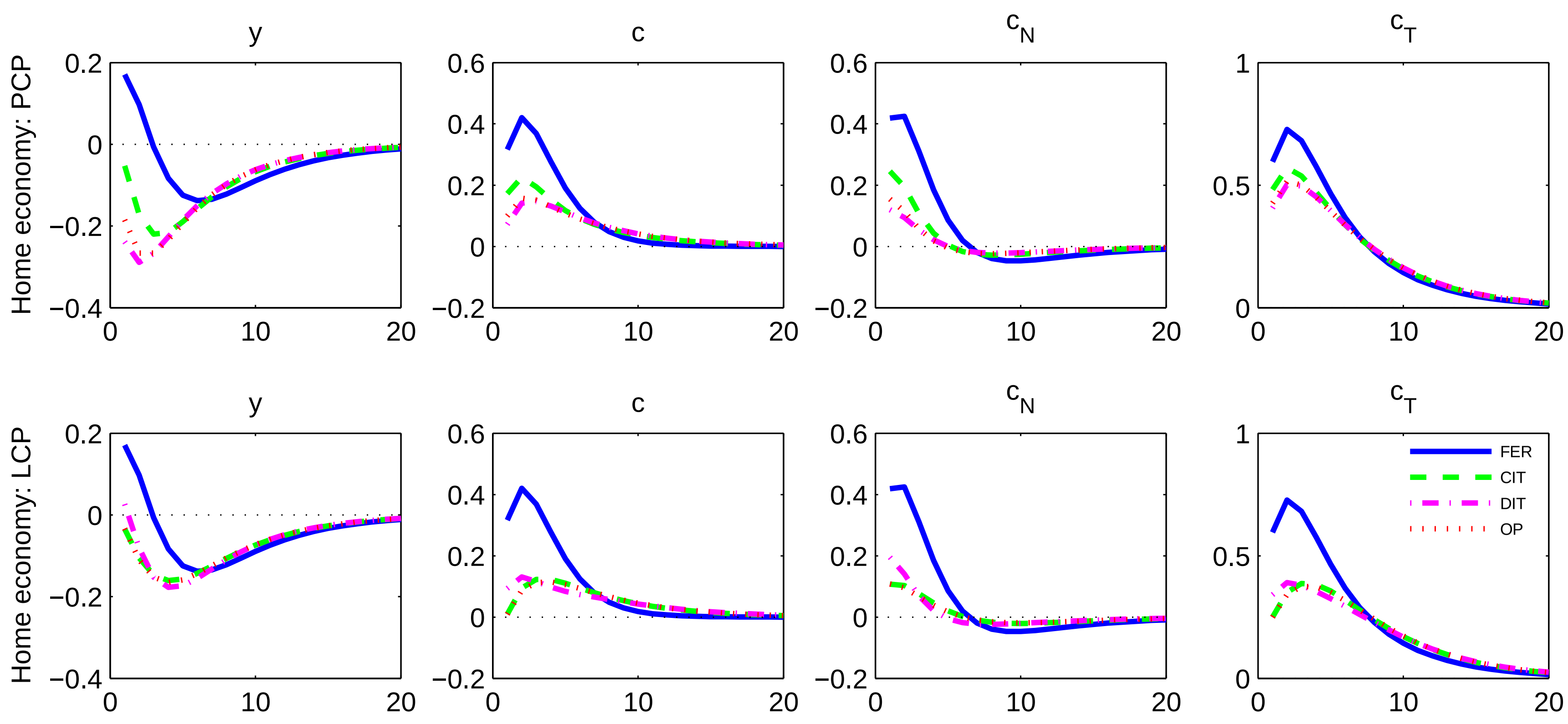
π - headline CPI inflation, π_B - core CPI inflation, π_D - domestic non-commodity output inflation, Δe - rate of change of the nominal exchange rate.

Figure C.5: Impulse responses to foreign commodity shock: home inflation



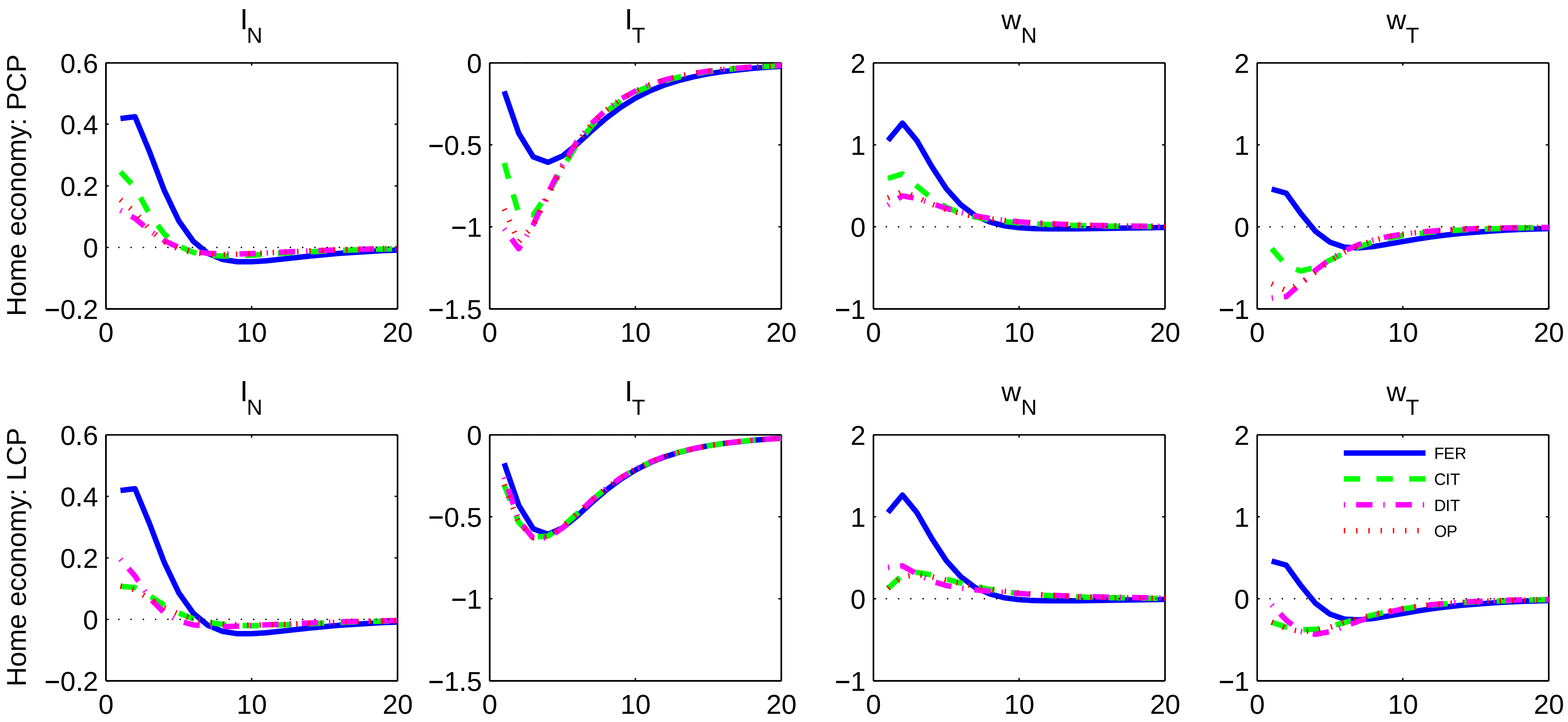
π_N - nontradable goods inflation, π_T - tradable goods inflation, π_H and π_H^* - inflation of home tradable goods supplied to home and foreign markets.

Figure C.6: Impulse responses to foreign commodity shock: home output and consumption



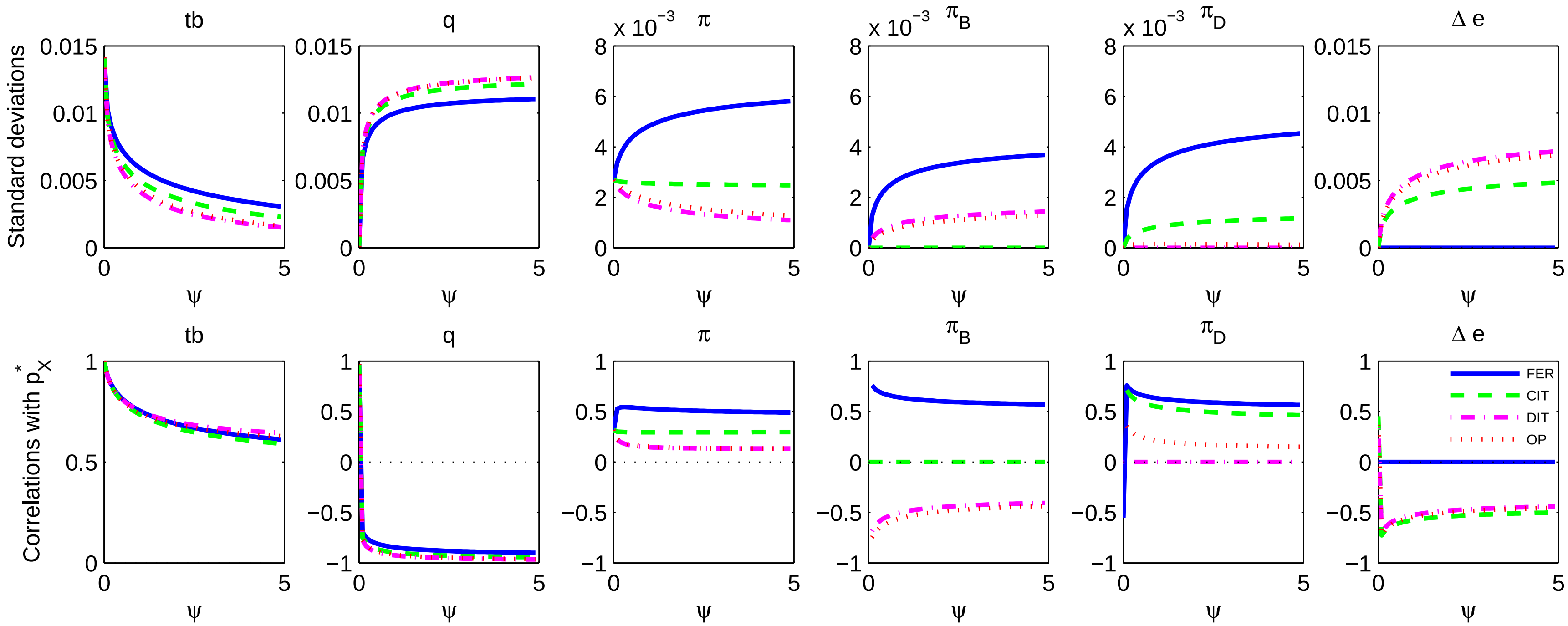
y - home output, c - home consumption, c_N and c_T - home consumption of nontradable and tradable goods.

Figure C.7: Impulse responses to foreign commodity shock: home labor and wages



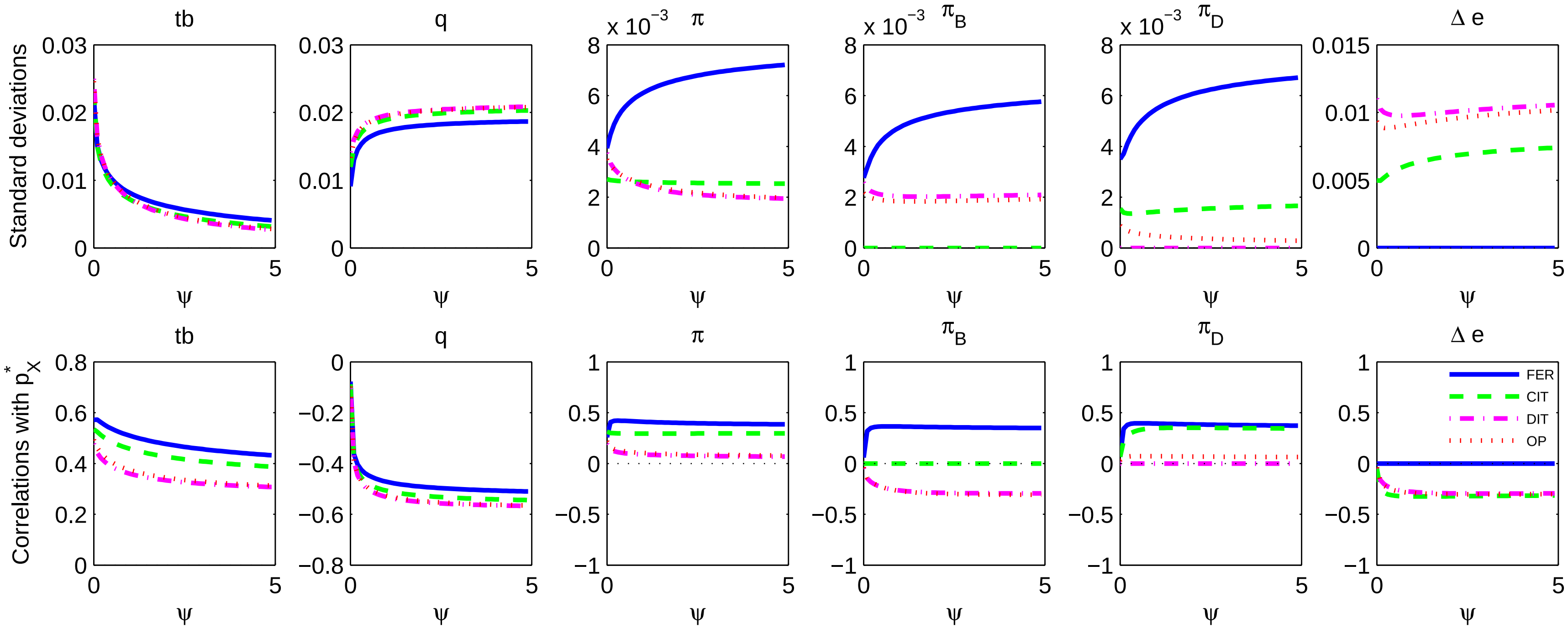
l_N and l_T - labor in home nontradable and tradable sectors, w_N and w_T - wages in home nontradable and tradable sectors.

Figure C.8: Business cycles statistics: foreign commodity shock only



p^*_X - real foreign commodity price, tb - trade balance (% of home steady-state output), q - real exchange rate, π - headline CPI inflation, π_B - core CPI inflation, π_D - domestic non-commodity output inflation, Δe - rate of change of the nominal exchange rate.

Figure C.9: Business cycles statistics: all shocks



p_X^* - real foreign commodity price, tb - trade balance (% of home steady-state output), q - real exchange rate, π - headline CPI inflation, π_B - core CPI inflation, π_D - domestic non-commodity output inflation, Δe - rate of change of the nominal exchange rate.

C.3 Tables

Table C.1: Standard deviations of the labor productivities in some OECD countries

Country	Commodity sector	Tradable sector	Nontradable sector
Germany	0.045	0.020	0.007
United Kingdom	0.066	0.022	0.013
France	0.040	0.014	0.006
Italy	0.029	0.024	0.011
Spain	0.045	0.013	0.013
Portugal	0.061	0.022	0.017
Netherlands	0.036	0.022	0.008
Belgium	0.045	0.024	0.008
Austria	0.029	0.017	0.007
Finland	0.049	0.029	0.012
Denmark	0.055	0.029	0.010
Norway	0.058	0.029	0.011
United States	0.053	0.020	0.007
Canada	0.034	0.028	0.008
Japan	0.044	0.029	0.016
Korea	0.043	0.033	0.016
Average	0.046	0.023	0.010

Source: OECD STAN, 1980-2008
Notes: data in logs, HP-filtered
Commodity sector - Agriculture, forestry and fishing, Mining and quarrying;
Tradable sector - Manufacturing;
Nontradable sector - Utilities, Construction, Services.

Table C.2: Calibration

Parameter	Description	Value
β	discount factor	0.99
σ	intertemporal elasticity of substitution (inverse)	2
ν	Frisch elasticity of labor supply (inverse)	1
ϵ	elasticity of substitution between nontradable, tradable goods and commodity	0.74
θ	elasticity of substitution between home and foreign tradable goods	1.5
η_N	elasticity of substitution between nontradable varieties	11
η_T	elasticity of substitution between tradable varieties	11
ω_N	share of nontradable firms with sticky prices	0.75
ω_T	share of tradable firms with sticky prices	0.75
γ	share of tradable firms with sticky prices using PCP	{0,1}
α_N	weight of nontradable goods in consumption basket	0.5
α_T	weight of tradable goods in consumption basket	0.4
α_H	weight of home tradable goods in consumption of tradables	0.5
A^*_N	productivity level in foreign nontradable sector	1
A^*_N	productivity level in foreign tradable sector	1
X^*	foreign commodity endowment	1
A_N	productivity level in home nontradable sector	1
A_T	productivity level in home tradable sector	1
X	home commodity endowment	{1, 4, 10}
ψ	financial intermediation costs	$\{0, 1, \infty\}$
$\rho_N,\ \rho^*_N$	persistence of productivity shocks in nontradable sector	0.8
$\rho_T,\ \rho^*_T$	persistence of productivity shocks in tradable sector	0.8
$\rho_X,\ \rho^*_X$	persistence of commodity shocks	0.8
$std(u_N),\ std(u^*_N)$	volatility of productivity shocks in nontradable sector	0.01
$std(u_T),\ std(u^*_T)$	volatility of productivity shocks in tradable sector	0.02
$std(u_X),\ std(u^*_X)$	volatility of commodity shocks	0.04

Table C.3: Deterministic steady-state equilibrium

		World	Home		
			$X = 1$	$X = 4$	$X = 10$
Welfare		-125,5	-125,5	-113,6	-96,9
Output					
total	y	1,176	1,176	1,247	1,407
nontradables	y_N	0,500	0,500	0,523	0,542
tradables	y_T	0,400	0,400	0,294	0,178
commodity	X	1,000	1,000	4,000	10,000
Consumption					
total	c	1,176	1,176	1,247	1,407
nontradables	c_N	0,500	0,500	0,523	0,542
tradables	c_T	0,400	0,400	0,429	0,528
home	c_H		0,200	0,203	0,177
foreign	c_F		0,200	0,226	0,377
commodity	c_X	1,000	1,000	1,102	1,573
Labor					
total	l_t	0,900	0,900	0,817	0,719
nontradables	l_N	0,500	0,500	0,523	0,542
tradables	l_T	0,400	0,400	0,294	0,178
Export					
total (value)	$p_H c_H^* + p_X(X - c_X)$		0,249	0,267	0,324
tradables (volume)	c_H^*		0,200	0,091	0,001
commodity (volume)	$X - c_X$		0,000	2,898	8,427
Import					
total (value)	$p_F c_F$		0,249	0,267	0,324
tradables (volume)	c_F		0,200	0,226	0,377
Prices					
nontradables	p_N	1,245	1,245	1,269	1,424
tradables	p_T	1,245	1,245	1,224	1,090
home	p_H		1,245	1,269	1,424
foreign	p_F		1,245	1,181	0,860
commodity	p_X	0,055	0,055	0,053	0,038
Wages					
nontradables	w_N	1,245	1,245	1,269	1,424
tradables	w_T	1,245	1,245	1,269	1,424
Real exchange rate	q		1,000	0,948	0,691

Table C.4: Business cycles statistics: foreign commodity shock only

Statistics	Home economy											
	$\psi = 0$				$\psi = 1$				$\psi \to \infty$			
	FER	CIT	DIT	OP	FER	CIT	DIT	OP	FER	CIT	DIT	OP
Standard Dev.												
GDP	0,06	0,06	0,06	0,06	0,39	0,49	0,60	0,58	0,95	0,58	0,77	0,75
Consumption	0,25	0,25	0,25	0,25	0,74	0,42	0,32	0,33	1,74	0,84	0,44	0,45
Trade balance (% of GDP)	1,41	1,41	1,41	1,41	0,59	0,50	0,41	0,44	0,00	0,00	0,00	0,00
Real exchange rate	0,01	0,01	0,01	0,01	1,00	1,10	1,14	1,13	1,15	1,27	1,32	1,32
Nominal exchange rate (% of change)	0,00	0,00	0,00	0,00	0,00	0,36	0,52	0,49	0,00	0,58	0,84	0,83
Headline CPI inflation	0,27	0,27	0,27	0,27	0,48	0,26	0,17	0,19	0,66	0,24	0,07	0,08
Core CPI inflation	0,00	0,00	0,00	0,00	0,28	0,00	0,10	0,08	0,44	0,00	0,17	0,16
Domestic inflation	0,00	0,00	0,00	0,00	0,35	0,08	0,00	0,01	0,54	0,14	0,00	0,01
Cross-correlations with real commodity price												
GDP	1,00	1,00	1,00	1,00	-0,01	-0,82	-0,97	-0,94	0,34	-0,77	-1,00	-1,00
Consumption	-1,00	-1,00	-1,00	-1,00	0,96	0,97	0,90	0,93	0,86	0,90	1,00	1,00
Trade balance (% of GDP)	1,00	1,00	1,00	1,00	0,75	0,73	0,75	0,74	–	–	–	–
Real exchange rate	0,97	0,97	0,97	0,97	-0,85	-0,90	-0,93	-0,92	-0,93	-0,97	-0,98	-0,98
Nominal exchange rate (% of change)	–	–	–	–	–	-0,57	-0,52	-0,54	–	-0,45	-0,40	-0,40
Headline CPI inflation	0,32	0,32	0,32	0,32	0,53	0,29	0,15	0,15	0,45	0,30	0,15	0,15
Core CPI inflation	–	–	–	–	0,63	–	-0,49	-0,55	0,52	–	-0,36	-0,37
Domestic inflation	–	–	–	–	0,63	0,54	–	0,21	0,51	0,40	–	0,13

Table C.5: Business cycles statistics: all shocks

Statistics	Home economy											
	$\psi = 0$				$\psi = 1$				$\psi \to \infty$			
	FER	CIT	DIT	OP	FER	CIT	DIT	OP	FER	CIT	DIT	OP
Standard Dev.												
GDP	1,76	1,92	2,24	2,19	1,64	1,41	1,51	1,53	2,14	1,40	1,37	1,38
Consumption	1,01	0,98	0,91	0,94	1,46	1,15	1,07	1,10	2,59	1,55	1,22	1,24
Trade balance (% of GDP)	2,22	2,31	2,50	2,46	0,81	0,72	0,73	0,75	0,00	0,00	0,00	0,00
Real exchange rate	0,91	1,20	1,41	1,33	1,73	1,90	1,96	1,95	1,93	2,09	2,14	2,14
Nominal exchange rate (% of change)	0,00	0,50	1,10	0,94	0,00	0,62	0,98	0,91	0,00	0,85	1,16	1,15
Headline CPI inflation	0,39	0,27	0,37	0,35	0,61	0,26	0,24	0,25	0,81	0,25	0,18	0,18
Core CPI inflation	0,28	0,00	0,26	0,22	0,48	0,00	0,20	0,18	0,66	0,00	0,23	0,22
Domestic inflation	0,35	0,16	0,00	0,09	0,55	0,14	0,00	0,05	0,77	0,19	0,00	0,01
Cross-correlations with real commodity price												
GDP	0,02	-0,01	-0,04	-0,03	-0,01	-0,30	-0,42	-0,38	0,14	-0,32	-0,57	-0,56
Consumption	-0,09	-0,11	-0,14	-0,12	0,53	0,41	0,31	0,32	0,58	0,50	0,37	0,38
Trade balance (% of GDP)	0,57	0,53	0,48	0,49	0,51	0,46	0,36	0,37	–	–	–	–
Real exchange rate	-0,08	-0,09	-0,10	-0,10	-0,47	-0,51	-0,53	-0,53	-0,53	-0,56	-0,58	-0,58
Nominal exchange rate (% of change)	–	-0,05	-0,04	-0,04	–	-0,33	-0,28	-0,29	–	-0,29	-0,28	-0,28
Headline CPI inflation	0,26	0,31	0,19	0,22	0,41	0,29	0,09	0,10	0,36	0,30	0,05	0,06
Core CPI inflation	0,06	–	-0,05	-0,04	0,36	–	-0,27	-0,27	0,33	–	-0,28	-0,29
Domestic inflation	0,07	0,06	–	0,03	0,39	0,35	–	0,07	0,35	0,31	–	0,06

Table C.6: Welfare evaluations: foreign commodity shock only

Welfare losses	Home economy											
	$\psi = 0$				$\psi = 1$				$\psi \to \infty$			
	FER	CIT	DIT	OP	FER	CIT	DIT	OP	FER	CIT	DIT	OP
PCP ($\gamma = 1$)												
$X = 1$	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
$X = 4$	0,00	0,00	0,00	0,00	-0,08	-0,02	-0,01	-0,01	-0,21	-0,03	-0,02	-0,02
$X = 10$	0,00	0,00	-0,01	0,00	-1,20	-0,16	-0,01	-0,01	-2,94	-0,57	-0,07	-0,02
LCP ($\gamma = 0$)												
$X = 1$	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
$X = 4$	0,00	0,00	0,00	0,00	-0,08	-0,02	-0,02	-0,02	-0,21	-0,03	-0,04	-0,03
$X = 10$	0,00	0,00	0,00	0,00	-1,20	-0,15	-0,19	-0,15	-2,95	-0,27	-0,33	-0,27

Table C.7: Welfare evaluations: all shocks

Welfare losses	Home economy											
	$\psi = 0$				$\psi = 1$				$\psi \to \infty$			
	FER	CIT	DIT	OP	FER	CIT	DIT	OP	FER	CIT	DIT	OP
PCP ($\gamma = 1$)												
$X = 1$	-0,11	-0,07	-0,06	-0,06	-0,14	-0,06	-0,06	-0,06	-0,18	-0,07	-0,07	-0,07
$X = 4$	-0,13	-0,07	-0,06	-0,06	-0,26	-0,09	-0,08	-0,08	-0,48	-0,12	-0,09	-0,09
$X = 10$	-0,24	-0,12	-0,10	-0,07	-2,09	-0,37	-0,11	-0,09	-4,80	-1,01	-0,19	-0,10
LCP ($\gamma = 0$)												
$X = 1$	-0,11	-0,06	-0,07	-0,06	-0,14	-0,05	-0,06	-0,04	-0,18	-0,04	-0,06	-0,04
$X = 4$	-0,13	-0,07	-0,08	-0,07	-0,26	-0,08	-0,08	-0,08	-0,49	-0,10	-0,12	-0,09
$X = 10$	-0,23	-0,13	-0,16	-0,12	-2,09	-0,35	-0,44	-0,35	-4,81	-0,54	-0,66	-0,53

Bibliography

Alvarez, F. and U. J. Jermann (2000): "Efficiency, Equilibrium, and Asset Pricing with Risk of Default," *Econometrica*, 68, 775–797.

Aoki, K. (2001): "Optimal Monetary Policy Responses to Relative-Price Changes," *Journal of Monetary Economics*, 48, 55 – 80.

Backus, D. K., P. J. Kehoe, and F. E. Kydland (1992): "International Real Business Cycles," *The Journal of Political Economy*, 100, 745–775.

Backus, D. K. and G. W. Smith (1993): "Consumption and real exchange rates in dynamic economies with non-traded goods," *Journal of International Economics*, 35, 297–316.

Bai, J. and S. Ng (2002): "Determining the Number of Factors in Approximate Factor Models," *Econometrica*, 70, 191–221.

Benigno, G. and P. Benigno (2003): "Price Stability in Open Economies," *Review of Economic Studies*, 70, 743–764.

Benigno, G. and C. Thoenissen (2007): "Consumption and Real Exchange Rates with Incomplete Markets and Non-traded Goods," *Journal of International Money and Finance*.

Bernanke, B., J. Boivin, and P. S. Eliasz (2005): "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach," *The Quarterly Journal of Economics*, 120, 387–422.

Bernanke, B. S. and J. Boivin (2003): "Monetary Policy in a Data-Rich Environment," *Journal of Monetary Economics*, 50, 525–546.

Betts, C. M. and T. J. Kehoe (2006): "U.S. Real Exchange Rate Fluctuations and Relative Price Fluctuations," *Journal of Monetary Economics*, 53, 1297–1326.

——— (2008): "Real Exchange Rate Movements and the Relative Price of Non-traded Goods," NBER Working Papers 14437, National Bureau of Economic Research, Inc.

Bils, M. and P. J. Klenow (2004): "Some Evidence on the Importance of Sticky Prices," *Journal of Political Economy*, 112, 947–985.

Bodenstein, M. (2008): "International Asset Markets and Real Exchange Rate Volatility," *Review of Economic Dynamics*, 11, 688–705.

Boivin, J. and M. P. Giannoni (2007): "Global Forces and Monetary Policy Effectiveness," in *International Dimensions of Monetary Policy*, National Bureau of Economic Research, Inc, NBER Chapters, 429–478.

Boivin, J., M. P. Giannoni, and I. Mihov (2009): "Sticky Prices and Monetary Policy: Evidence from Disaggregated US Data," *American Economic Review*, 99, 350–84.

Brandt, M. W., J. H. Cochrane, and 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.

Bruno, M. and J. Sachs (1982): "Energy and Resource Allocation: A Dynamic Model of the "Dutch Disease"," *The Review of Economic Studies*, 49, 845–859.

Calvo, G. A. (1983): "Staggered Pricing in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, 383–398.

Cashin, P., L. F. Cespedes, and R. Sahay (2004): "Commodity Currencies and the Real Exchange Rate," *Journal of Development Economics*, 75, 239–268.

Chari, V. V., P. J. Kehoe, and E. R. McGrattan (2002): "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?" *Review of Economic Studies*, 69, 533–63.

Charnavoki, V. (2009): "Commodity Price Shocks and Real Business Cycles in a Small Commodity-Exporting Economy," mimeo.

Chen, Y. and K. Rogoff (2003): "Commodity Currencies," *Journal of International Economics*, 60, 133–160.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (1997): "Sticky Price and Limited Participation Models of Money: A Comparison," *European Economic Review*, 41, 1201–1249.

Corden, W. M. (1984): "Booming Sector and Dutch Disease Economics: Survey and Consolidation," *Oxford Economic Papers*, 36, pp. 359–380.

Corden, W. M. and J. P. Neary (1982): "Booming Sector and De-Industrialisation in a Small Open Economy," *Economic Journal*, 92, 825–48.

Corsetti, G., L. Dedola, and S. Leduc (2008): "International Risk Sharing and the Transmission of Productivity Shocks," *Review of Economic Studies*, 75, 443–473.

——— (2010): "Optimal Monetary Policy in Open Economies," Working papers, Federal Reserve Bank of San Francisco.

Corsetti, G. and P. Pesenti (2001): "Welfare And Macroeconomic Interdependence," *The Quarterly Journal of Economics*, 116, 421–445.

Dib, A. (2008): "Welfare Effects of Commodity Price and Exchange Rate Volatilities in a Multi-Sector Small Open Economy Model," Working papers, Bank of Canada.

Forni, M., D. Giannone, M. Lippi, and L. Reichlin (2009): "Opening The Black Box: Structural Factor Models With Large Cross Sections," *Econometric Theory*, 25, 1319–1347.

Frankel, J. A. (2010): "The Natural Resource Curse: A Survey," Working Paper 15836, National Bureau of Economic Research.

Gali, J. and T. Monacelli (2005): "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 707–734.

Gopinath, G. and R. Rigobon (2008): "Sticky Borders," *The Quarterly Journal of Economics*, 123, 531–575.

Hamilton, J. D. (2011): "Historical Oil Shocks," Working Paper 16790, National Bureau of Economic Research.

Horvath, M. (2000): "Sectoral Shocks and Aggregate Fluctuations," *Journal of Monetary Economics*, 45, 69 – 106.

Itskhoki, O. (2007): "How Expensive is Commitment?" Working paper, Harvard University.

Kehoe, P. J. and F. Perri (2002): "International Business Cycles with Endogenous Incomplete Markets," *Econometrica*, 70, 907–928.

Kilian, L. (2006): "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?" *Review of Economics and Statistics*, 90, 216–240.

——— (2009): "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review*, 99, 1053–69.

KILIAN, L. AND D. MURPHY (2010): "Why Agnostic Sign Restrictions Are Not Enough: Understanding the Dynamics of Oil Market VAR Models," Working paper.

KILIAN, L., A. REBUCCI, AND N. SPATAFORA (2009): "Oil Shocks and External Balances," *Journal of International Economics*, 77, 181–194.

KIM, J. AND S. H. KIM (2003): "Spurious Welfare Reversals in International Business Cycle Models," *Journal of International Economics*, 60, 471–500.

KIM, K. AND Y. S. KIM (2006): "How Important is the Intermediate Input Channel in Explaining Sectoral Employment Comovement over the Business Cycle?" *Review of Economic Dynamics*, 9, 659–682.

KLEIN, P. (2000): "Using the generalized Schur form to solve a multivariate linear rational expectations model," *Journal of Economic Dynamics and Control*, 24, 1405–1423.

KOLLMANN, R. (2002): "Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles," *Journal of Monetary Economics*, 49, 989–1015.

KOOP, G., D. J. POIRIER, AND J. L. TOBIAS (2007): *Bayesian Econometric Methods*, Cambridge University Press.

KOREN, M. AND S. TENREYRO (2007): "Volatility and Development," *The Quarterly Journal of Economics*, 122, 243–287.

KOSE, M. A. (2002): "Explaining Business Cycles in Small Open Economies: 'How Much Do World Prices Matter?'," *Journal of International Economics*, 56, 299–327.

KOSE, M. A., C. OTROK, AND C. H. WHITEMAN (2003): "International Business Cycles: World, Region, and Country-Specific Factors," *American Economic Review*, 93, 1216–1239.

LEVIN, A. T., A. ONATSKI, J. WILLIAMS, AND N. M. WILLIAMS (2006): "Monetary Policy Under Uncertainty in Micro-Founded Macroeconometric Models," in *NBER Macroeconomics Annual 2005, Volume 20*, National Bureau of Economic Research, Inc, NBER Chapters, 229–312.

LIPPI, F. AND A. NOBILI (2009): "Oil and the Macroeconomy: a Quantitative Structural Analysis," Temi di discussione (Economic working papers) 704, Bank of Italy, Economic Research Department.

LUCAS, R. E. (1991): *Models of Business Cycles*, Wiley-Blackwell.

MENDOZA, E. (1991): "Real Business Cycles in a Small Open Economy," *The American Economic Review*, 81, 797–818.

Mendoza, E. G. (1995): "The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations," *International Economic Review*, 36, 101–137.

Mumtaz, H. and P. Surico (2009): "The Transmission of International Shocks: A Factor-Augmented VAR Approach," *Journal of Money, Credit and Banking*, 41, 71–100.

Rao, S., J. Tang, and W. Wang (2004): "Measuring the Canada-U.S. Productivity Gap: Industry Dimensions," *International Productivity Monitor*, 9, 3–14.

Rauch, J. E. (1999): "Networks versus Markets in International Trade," *Journal of International Economics*, 48, 7–35.

Rotemberg, J. J. and M. Woodford (1996): "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," *Journal of Money, Credit and Banking*, 28, 549–577.

Rubio-Ramirez, J. F., D. F. Waggoner, and T. Zha (2010): "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference," *Review of Economic Studies*, 77, 665–696.

Ruhl, K. J. (2004): "The International Elasticity Puzzle," Working papers, NYU Stern School of Business.

Schmitt-Grohe, S. and M. Uribe (2003): "Closing small open economy models," *Journal of International Economics*, 61, 163–185.

——— (2004): "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function," *Journal of Economic Dynamics and Control*, 28, 755–775.

Sims, C. A. (2002): "Solving Linear Rational Expectations Models," *Computational Economics*, 20, 1–20.

Sosunov, K. and O. Zamulin (2007): "Monetary Policy in an Economy Sick with Dutch Disease," Tech. Rep. 101.

Spatafora, N. and A. M. Warner (1999): "Macroeconomic and Sectoral Effects of Terms-of-Trade Shocks - The Experience of the Oil-Exporting Developing Countries," IMF Working Papers 99/134, International Monetary Fund.

Stijns, J.-P. (2003): "An Empirical Test of the Dutch Disease Hypothesis using a Gravity Model of Trade," .

STOCK, J. H. AND M. W. WATSON (2005): "Implications of Dynamic Factor Models for VAR Analysis," Working Paper 11467, National Bureau of Economic Research.

VERDELHAN, A. (2010): "A Habit-Based Explanation of the Exchange Rate Risk Premium," *Journal of Finance*, 65, 123–146.

WOODFORD, M. (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

——— (2010): "Optimal Monetary Stabilization Policy," Working Paper 16095, National Bureau of Economic Research.