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Commodity Prices and Business Cycle in Emerging Economies: The Role of News Shocks

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Recife, 17/02/2017.

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Abstract

It is commonly accepted in macroeconomic literature that fluctuation in commodity prices are a key source of business cycles in emerging economies. In this present work, we explore the hypothesis that some movements in commodity prices are anticipated and can trigger fluctuation in the economy in the context of a dynamic stochastic general equilibrium model. The model is a multi-sector version of a small open economy model featuring three real rigidities: internal habit formation, capital adjustment cost and working capital constraint. Moreover, the model presents two exogenous processes, one for the country-specific interest rate that can respond to commodity price level, and one for commodity prices that are composed by an unanticipated and an anticipated component. We first perform a formulation for anticipated shocks that exploits the fact that agents receive news about future fundamentals as small shocks. Then, we explore a formulation where news shocks could only trigger business cycles through changes in agents' expectation, which is called "Pigou cycles" in the macroeconomic literature . We show that the model presented in this work can generate reasonable dynamics regarding unexpected shocks in fundamentals. Moreover, the model suggest that news shocks can be a significant source of business cycles in emerging economies, helping to explain around 32% of fluctuation in output and hours worked, but only with the implicit assumption that news about future changes in commodity price can affect current level in this exogenous process.

Keywords: DSGE. News shocks. Small Open Economies.

Resumo

É comumente aceito na literatura macroeconômica que flutuações nos preços das commodities é uma importante fonte de ciclos econômicos nas economias emergentes. Neste presente trabalho, nós exploramos a hipótese de que alguns movimentos nos preços das commodities são antecipados e podem provocar flutuações na economia no contexto de um modelo estocástico de equilíbrio geral dinâmico. O modelo é uma versão multi-setor do modelo de pequenas economias aberta com três rigidezes reais: formação de hábitos interno, custo de ajuste de capital e restrição de capital de giro. Além disso, o modelo apresenta dois processos exógenos, um para a taxa de juros que o país enfrenta nos mercados internacionais de crédito, que pode responder ao nível de preços das commodities, e um processo para o preços de commodity que é composto por um componente não-antecipado e um componente antecipado. Primeiramente, nós realizamos uma formulação para choques antecipados que explora o fato de que os agentes recebem notícias sobre mudanças futuras nos processos estocásticos como pequenos choques. Depois disso, nós exploramos uma formulação em que os choques de notícias só poderiam desencadear flutuações econômicas através de mudanças na expectativa dos agentes, o que é conhecido como "ciclos de Pigou" na literatura macroeconômica. Nós mostramos que o modelo apresentado neste trabalho pode gerar dinâmicas razoáveis em relação a choques inesperados nos processos estocásticos. Além disso, o modelo sugere que os choques de notícia podem ser uma fonte significativa de ciclos econômicos nas economias emergentes, ajudando a explicar cerca de 32% da flutuação no PIB e em horas-trabalhadas, mas apenas com implícita suposição de que as notícias sobre mudanças futuras no preço das commodities podem afetar o nível atual desses preços.

Palavras-chave: DSGE. Choques antecipados. Pequenas Economias abertas.

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CHAPTER 1

Introduction

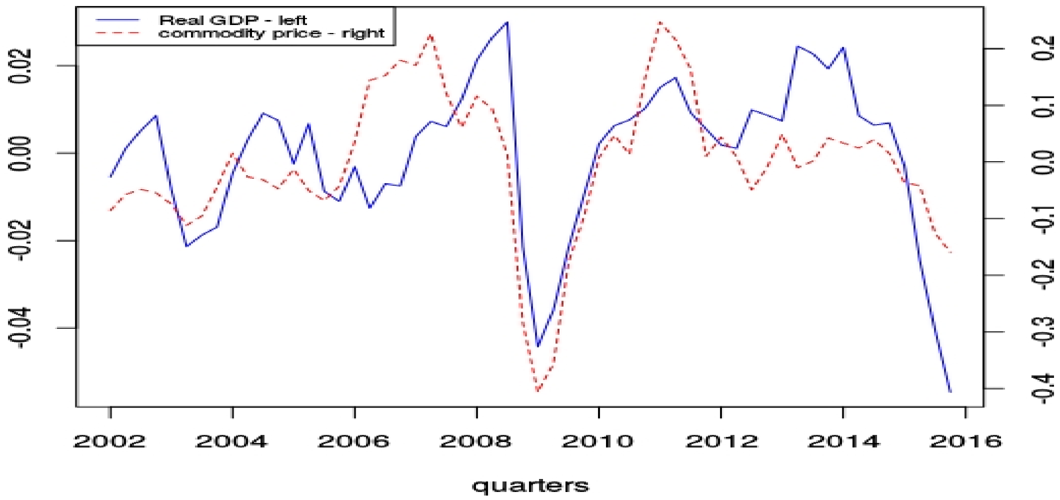
The phenomenon of globalization has brought down obstacles to trade and investment relations and has connected countries all around the world in a global supply chain. And in this dynamism a group of economies, namely emerging economies, has been playing a significant role in these commercial relations, specially as commodity exporters. The opening of these countries to global financial capital, technology, and talent markets has fundamentally changed their economic and business environments. For instance, emerging economies such as Brazil, Colombia, Chile, South Africa, experienced fast economic growth during the first decade of the 21st, and has lifted thousands out of poverty and creating new consumer markets for a variety of new products and services. However, these countries are also at the mercy of external forces that could trigger fluctuation in their economy.

It has been commonly accepted in the macroeconomic literature that one of the major key drivers for business cycle in emerging economies is commodity price fluctuations. One of the reasons for this conventional wisdom is that these countries have a significant share of commodities in total exports and in gross domestic product (GDP). Data from the United Nations International Trade Statistics Database (UN COMTRADE), for instance, shows that over the 1994-2016 period, Brazil, Chile, Colombia, Mexico and South Africa displayed an average share of commodities in total exports of around 60%. Moreover, during the same period, the average share of commodities in GDP was about 13% for these emerging economies. As an example to illustrate how commodity prices could be associated with fluctuation in emerging economies, Figure 1.1 displays how the cycle of Brazilian output are strongly related to the the cycle of commodity export price[1].

[1]It was used quarterly real GDP as output and Industrial Inputs Price Index (PINDU) as commodity price from IMF database. Output was seasonally adjusted using X-13 ARIMA-SEATS. Commodity price was deflated using US CPI price index. Cyclical components were obtained with Hodrick-Prescott filter ($\lambda = 1600$).

Thus, given the relevance that commodity goods have in these economies and how the volatility of its price might be linked to macroeconomic fluctuations, it is important to understanding how the economic activity respond to commodity price fluctuations.

Figure 1.1: Commodity export prices and real GDP for Brazil.



Source: IMF Primary Commodity Price System and National accounts. The period analyzed was 2002:Q1-2015:Q4.

As extensively investigated in the literature, there are different channels in which a commodity price shock might affect an economy. The conventional one is the spillover effect, which can be explained as follows: when a higher commodity price increases the revenues of the exporting sector, this might have the potential to affect the others sectors in the economy. There is a extensive list of work focusing on the effects of an unexpected commodity price shocks. For instance, Kilian (2008), Kilian & Lewis (2011), Filardo & Lombardi (2014) have focused on the effects of unexpected commodity price shocks on developed countries, and Silva (2011), Camacho & Perez-Quiros (2014), Fernández et al. (2015), Fornero et al. (2016) and Shousha (2016) have aimed attention at emerging countries.

Another interesting channel is the effect of commodity price shocks on the interest rate faced by commodity exporters in the international financial markets. Interest rates that emerging economies faced in these markets are composed of two components: one is the risk free interest rate, which mostly reflects the U.S. Treasury bill interest rate, and the other is country-specific spread, which reflects a compensation for investors who tolerate the extra risk for investing in these countries rather than in a risk-free asset. More recently, Bastourre et al. (2012), Fernández et al. (2015) and Shousha (2016) documented the relation between commodity prices and country spreads relative to U.S. bond and found that periods when commodity prices were high (low), tend to coincided with low (high) interest rate faced by emerging economies in international financial markets. Moreover, they showed that the effects of a commodity price shock can be amplified by the fact they are often accompanied by movements in interest rates in opposite directions, deepening the effects of this shock to the rest of the economy through a change in financial conditions for all sectors.

In this current work, we explore a hypothesis that has gained a renewed interest in theories of business cycles: the role of *news* shocks. The term *news* are defined in the literature as signals that the economy receives about future changes in some fundamental. In this context, these signals could trigger fluctuation in the economy, as the agents could react to such informations by changing their decisions before the fundamental shock materializes. It is in this sense that some fluctuations in the economy could be generated, as some movements in commodity prices can be anticipated, since the underlying cause of changes in commodity prices are recognized by agents, and, considering that the agents are able to learn from these signals, they can respond to them by adjust their current behavior. For instance, according to Kilian & Hicks (2013), the growth in commodity prices experienced from mid 2003 until mid 2008 was largely explained by news about global growth. One explanation was that upward revisions of real GDP forecasts, especially for India and China, were signals (news) of a booming world economy that prompted additional demand for commodity goods, which leaded to high levels of commodity prices. Also, as Zeev et al. (2016) stated, the existence of future markets for commodity goods supports the idea that some movements in commodity prices are anticipated, since future prices could provide forecast of future commodity prices. Therefore, it is crucial to understand whether these anticipated movements in commodity prices can play a non-negligible role in explaining business cycles in emerging economies.

A large literature has given attention to news shocks as a key driver for business cycles. Beaudry & Portier (2006) provided evidence in favor of this hypothesis studying news about total factor productivity (TFP) in the context of structural VAR and arguing that this type of shock explains about half of the fluctuation in the U.S. economy. Additionally, Barsky & Sims (2011) proposing a new identification strategy VAR approach for news shocks, concluded that news shocks also account for a significant fraction of output fluctuations. Using a DSGE approach, Schmitt-Grohé & Uribe (2012) evaluated the role of news about future fundamentals and showed that expected shocks account for around half of the fluctuations in the U.S., and Miyamoto & Nguyen (2014) using the same model as in Schmitt-Grohé & Uribe (2012) but with data on expectation, found that news shocks explain a lesser fraction of aggregate fluctuation than stated before. More recently, Zeev et al. (2016) investigated the importance of unanticipated and anticipated terms-of-trade (TOT) shocks for Latin American countries and showed that TOT news shocks matter more than unexpected TOT shocks for business cycles fluctuations in emerging countries.

This present work aims to investigate the role of anticipated commodity price shocks in explaining business cycle and account for their importance in generating output fluctuation using a small open economy model. The idea behind it is that once agents can recognize these signals about future change in commodity prices, they will adjust expectations about the future of the economy, affecting their current optimal decisions. Thus, good news would lead to high expectations by the agents that, in turn, might prompt high levels of investment and a slight economic boom. Our analysis proceeds as follows: we first present a multi-sector version of a small open economy model featuring an interest rate process that responds to commodity price levels and a commodity price process with two sources of disturbance (an unexpected component and an anticipated one); further, we also consider the unexpected shocks in fundamentals and investigate the ability of the small open economy model to generate suitable responses regarding unexpected shocks in the economic system. Thereafter, we consider the effect of anticipated shocks by formulating that the economy model receives two signals (news) about a future change in commodity prices. These signals are revealed with four and two periods in advance to agents and reflects small shocks in commodity price. These news shocks formulation is similar to the one used in Beaudry & Portier (2006), Barsky & Sims (2011), Schmitt-Grohé & Uribe (2012), and Zeev et al. (2016), on which news shocks represent a slow diffusing change of a future innovation in the fundamental process in the economy model. Finally, we consider an alternative formulation for news shock, what we call "pure" news, on which the release of this signal could only affect the agents' expectation and not the current fundamental process. The business cycle that could be generated from this formulation is called in the literature "Pigou cycles" and this formulation is similar to the one used by Beaudry & Portier (2004) and Beaudry et al. (2011).

We find that the model presented in this work produces adequate responses according to the business cycles literature regarding unexpected shocks in commodity prices, interest rate and TFP. We then proceed the analysis with news shocks. Our main finding is that, in the context of the presented model, news about commodity prices might be a non-negligible source of business cycles in emerging economies, helping to explain an average of 32% of fluctuation in output and hours worked, a result in line with what was found in Zeev et al. (2016). However, this result only holds when we consider that news about future changes in commodity prices can affect the current process. Moreover, when we perform the alternative formulation of news shocks, we find that a "pure" news plays a minor role in explaining business cycles in the model. This result is in line with what was found in Miyamoto & Nguyen (2014), who showed that news shocks play a trivial role in explaining business cycles before the fundamental shock materializes.

The remainder of this work is as follows. In chapter 2, we discuss the relationship of this work with the literature. Chapter 3 presents the details of the small open economy model. In chapter 4, we discuss the results regarding the ability of the model in generating reasonable responses concerning unexpected shocks and the results regarding the news shocks. Finally, chapter 5 concludes.

CHAPTER 2

Relationship with the Literature

This work is related to the literature that studies the effects of external shocks in emerging economies. In this branch of the literature, external shocks in terms of trade, commodity price and international interest rate are seen as important sources of disturbance for these economies. Mendoza (1995) were the first to analyze the importance of terms of trade (TOT) in driving business cycles using a dynamic stochastic small open economy model and showed that TOT shocks explained the majority of aggregate output fluctuations. Kose (2002) analyzing the effects of world prices shocks, namely world interest, prices of capital, intermediate, and primary goods, on small open economies showed that world price shocks play an important role in driving business cycles in small open developing economies, explaining roughly 88% of aggregate output fluctuations. Recently, Schmitt-Grohé & Uribe (2015) showed that when using empirical and theoretical models the importance attributed to TOT shocks in explaining business cycles in emerging economies differs considerably, indicating that TOT shocks is three times as stronger in theoretical model than empirical VAR approach. Camacho & Perez-Quiros (2014) analyzed the effects of commodity prices shocks on output growth in Argentina, Brazil, Colombia, Chile, Mexico, Peru and Venezuela using a multivariate Markov-switching model. They provided evidences on the nonlinear responses of output growth to commodity prices and that their effects on output growth depend on the state of the economy, the size of the shock and the sign of the shock. Fornero et al. (2016) explored the fact that commodity exporters, such as Brazil, Chile, Peru, experienced significant deterioration in current account even with the surge in commodity prices in the past decade. Using an estimated dynamic stochastic general equilibrium (DSGE) model, which agents can not perfectly distinguish between persistent and transitory movements in commodity prices, for Chilean data, they showed that if the shock is believed to be high, then a higher expected rate of return of capital triggers a boom in the economy. Moreover, they showed that a relative fraction of investment and current account balance in Chile are explained by commodity price fluctuation. Further, Silva (2011), using a Vector Autoregressive (VAR) with sign restriction approach, analyzed the effects of domestic and external shocks on fluctuation in emerging economies and showed that the response of real output regarding commodity price shocks differs across countries, demonstrating an improvement for Brazil and Chile, while for Mexico and Colombia an opposite effect. In addition, he showed that a favorable U.S. business cycle shock has a positive effect on these countries, whereas a U.S. monetary policy shock has negative effects on real output for all countries, but Chile. Fernández et al. (2015) documented that emerging economies are, on average, commodity exporters, the interest rate faced by these economies in international markets are countercyclical with commodity price, and a considerable share of the variance in commodity prices is explained by common factors. Guided by these facts, they embed into a DSGE model a commodity price and an interest rate process featuring a common dynamic factor structure and estimated using emerging economies data. They found that common factor can play an important role in explaining fluctuation in these economies. Shousha (2016), using a panel VAR approach, shows that commodity price shocks are an important source of business cycles in small open commodity exporter economies and their effects can be amplified by the movements in international interest rate in opposite direction, but with stronger effects for emerging economies rather than for advanced countries. Further, in order to assess which channels are responsible for this contrast in responses among emerging and advanced economies, he built a multi-sector small open economy model with financial frictions and concluded that the most relevant channels for the transmission of commodity price shocks were the interest rate faced by the economy in international markets and working capital constraint. Neumeyer & Perri (2005) and Uribe & Yue (2006) analyze the effect of international interest rate shocks in emerging economies. They defined international interest shocks as the interest rate faced by emerging economies in world financial markets and were composed by two components: U.S. interest rate and country spread. They showed that U.S. interest rate and country spread shocks are crucial drivers of business cycle in emerging economies, with country spread playing a significant role in propagating the U.S. interest rate shocks. As it can be noted from this briefly review, the existing literature on the sources of business cycles implicitly assumes that the totality of aggregate fluctuations is due to unexpected or unanticipated shocks. We contribute to this literature by providing an indication of a new source of disturbance to account for business cycle in emerging economies and showing that anticipated shocks in commodity prices might be a non-negligible component in explaining business cycle in these economies.

This work is also related to the literature of news shocks. The idea that changes in expectations about future path of exogenous fundamentals may trigger aggregate fluctuation has a long history in economics, going back at least to Pigou. It was recovered in Cochrane (1994), who showed that none of the popular candidates shocks, namely oil prices, technology, credit shocks, robustly accounts for the bulk of business cycle in output, whereas VARs estimated using simulated data from a real business cycle (RBC) model driven by contemporaneous and news shocks to technology could resemble the corresponding responses implied by VARs on actual U.S. data. Beaudry & Portier (2004) explored a theory of business cycles on which recessions and booms arise due to difficulties encountered by the agents in forecasting the future needs of capital, which they called "Pigou cycles". They presented a model with three sectors where agents get imperfect signals (news) about future productivity growth and use these signals they get to make decisions about investment, and showed that forecast errors may be a key source in understanding business cycle, as in their model a boom and a recession can arise as the result of overly optimistic expectation about future technological growth. Beaudry & Portier (2006) explored how stock price movements could be used to extract information on any changes in agents' expectation about future economic fluctuations and proposed an identification scheme for uncovering anticipated shocks in the context of a VAR. They found that innovations in the growth rate of TFP are reflected in stock price fluctuation many quarters in advance (that is, technology improvement diffuses slowly overtime) and that anticipated shocks explained about half of the fluctuation in consumption, output and hours worked. Jaimovich & Rebelo (2009) proposed a model that generates both aggregate and sectoral movements in response to contemporaneous and news shocks. The fundamentals considered by them were aggregate and sectoral TFP and investment-specific technical changes. Using a model with variable capital utilization, investment adjustment cost and a form of preference that allowed to parameterize the strength of wealth effect on labor, they showed that a news shock displayed an expansion in consumption, investment, output, hours worked, before the shock materialize itself. Beaudry et al. (2011) explored business cycles co-movements within and between countries by first shown that news shocks are powerful source of joint co-movements across countries, and then proposing a two country model that allows for news shocks to propagate and generate international business cycles. Barsky & Sims (2011) proposed a novel identification strategy VAR approach to study news shocks. News shocks was identified as the the shock orthogonal to the fundamental innovation that best explain future variation in the fundamental itself. They showed that a good news shocks was associated with a positive impact in consumption and declines in output, investment and hours of work. Schmitt-Grohé & Uribe (2012) investigated how important are anticipated shocks as a source of economic fluctuations in U.S. economy. Employing a RBC model augmented with four real rigidities (internal habit formation in consumption, investment adjustment cost, variable capacity utilization, and imperfect competition in labor markets), driven by seven structural shocks, namely, stationary and nonstationary neutral TFP shocks, stationary and nonstationary investment-specific shocks, government spending shocks, wage markup shocks, preference shocks, they showed that anticipated explain about one half of the fluctuations in the model, and Miyamoto & Nguyen (2014), using data on expectation and incorporating into the model used in Schmitt-Grohé & Uribe (2012), found that the contribution of news shocks is about half of that estimated without this type of data. Moreover, they also found that news shocks play a negligible role in explaining short run fluctuations, that is, in explaining business cycle before the shock materializes. More recently, Zeev et al. (2016) explored the disconnect between empirical and theoretical results regarding shocks in terms of trade found in Schmitt-Grohé & Uribe (2015). To address this issue, they argued that TOT process are composed by an anticipated component. They employ an alternative empirical identification strategy for extracting news about TOT in the data and identify TOT news shocks as shocks that best explain future movements in terms of trade over a horizon of one year, and that are orthogonal to current TOT movements. They found that unexpected TOT shocks explain an average of 12% in output fluctuation, whereas news about TOT shocks explain an average of 25% in the same variable. We contribute to this branch of the literature by presenting a small open economy model that could be used to assess the role of anticipated shocks in commodity price process, a fundamental that, at the time of this writing, was not explored yet. Moreover, we find that anticipated commodity prices shocks can be a non-negligible source of business cycles in the model, however this result is true when we implicitly assume that news about future changes in commodity prices can affect the current process. Additionally, we find that when we consider a formulation of news that could only trigger fluctuation in the economy by changing agents' expectation, this "pure" news plays a minor role helping to explain business cycle in the context of the model presented in this work.

CHAPTER 3

Methodology

We will use a Dynamic Stochastic General Equilibrium (DSGE) model designed to represent a small open economy to assess the role of news about commodity price shocks to the economy. The next sections introduce the DSGE model.

3.1 Theoretical Model

In this section, we present a model to evaluate the effects of unanticipated and anticipated commodity price shocks to account for business cycles in emerging economies. The structure of the model is similar to the one used by Schmitt-Grohé & Uribe (2015) with some departures: first, we are considering commodity price shocks rather than terms of trade shocks to account for business cycles. Second, we use three different sectors: a tradable final good, a nontradable final good and a commodity sector. Commodities can be used either as input in the local production or exported to international markets. In this design, the commodity production is endogenous to the model rather than an endowment as in Fernández et al. (2015). This element introduces an indirect effect of changes in commodity prices to other sectors, as optimal decisions from this sector will affect the rate of return of production factors. Third, the model features three real rigidities: internal habit formation in consumption, capital adjustment cost and working capital constraint.[1] Forth, the interest rate faced by the economy in the international financial markets can also be affected by commodity price. This feature has been documented in Fernández et al. (2015) and can represent an amplification mechanism of commodity price shocks through a financial channel. Fifth, we are considering a exogenous commodity price pro-

[1]The introduction of these elements will assist the model in preventing investment volatility, induce persistence in consumption and allow for a direct effect of interest rate changes in the supply side of the model.

cess that are subject to two sources of disturbance: an unanticipated and an anticipated component. The assumption behind this approach is the fact that some movements in this exogenous process can be anticipated by forward-looking agents that will react to these signals (news) generating an earlier response to the economic variables.

3.1.1 Households

The economy model is a small open economy populated by a large number of identical households that consume a basket of tradable and nontradable goods. The consumption basket is a CES aggregator with elasticity of substitution φ between tradable (c_t^T) and nontradable goods (c_t^N):

$$c_t \equiv A(c_t^T, c_t^N) = [\chi (c_t^T)^{\frac{\varphi-1}{\varphi}} + (1-\chi)(c_t^N)^{\frac{\varphi-1}{\varphi}}]^{\frac{\varphi}{\varphi-1}},$$

where $\chi \in (0,1)$, represents the share of tradable goods in the consumption basket.

The representative household have preferences described by utility function featuring internal habit formation in consumption[2]:

$$U(c_t, l_t^T, l_t^N, l_t^{CM}) = \frac{[c_t - \tau c_{t-1} - H(l_t^T, l_t^N, l_t^{CM})]^{1-\sigma} - 1}{1-\sigma},$$

where

$$H(l_t^T, l_t^N, l_t^{CM}) = \frac{(l_t^T)^{\omega^T}}{\omega^T} + \frac{(l_t^N)^{\omega^N}}{\omega^N} + \frac{(l_t^{CM})^{\omega^{CM}}}{\omega^{CM}},$$

and l_t^T, l_t^N, l_t^{CM} are, respectively, hours worked in the tradable sector, nontradable sector and commodity sector, $\sigma > 0$ is the coefficient of relative risk aversion and $\omega_T, \omega_N, \omega_{CM}$ are the Frisch elasticity of labor supply for each sector, and the parameter $\tau \in (0,1)$ denotes the intensity of internal habit formation[3].

The households' lifetime utility is given by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}), \tag{3.1}$$

where $\beta \in (0,1)$ is the subjective discount factor.

Households have access to two types of assets: a physical capital and an international financial asset. They own all the physical capital in the economy and can issue bonds in the international financial markets in order to smooth consumption. Also, all firms in the economy are assumed to be owned by households, who will receive all the profits. Thus, households have four sources of income: wages, physical capital rents, international

[2] This type of utility function is described in Greenwood et al. (1988). A key feature of GHH preference is that there is no income effect on households labor supply.

[3] Under habit persistence, an increase in current consumption lowers the marginal utility of consumption in the current period and increases it in the next period. In other words, the more the agent consumes today, the hungrier he will be tomorrow.

borrowing and profits from firms. Every period they allocate their income consuming tradable and nontradable goods, choosing how much to invest in order to replace depreciated capital and increase the net stock of capital, for which they face adjustment costs, and paying interest rate for their debt holdings. Thus, their period-by-period budget constraint, in terms of the numeraire tradable good, is given by

$$c_t^T + p_t^N c_t^N + \sum_i [I_t^i + \Phi_i(K_{t+1}^i, K_t^i)] + r_{t-1} d_{t-1}^H = (d_t^H - d_{t-1}^H) + \sum_i (w_t^i l_t^i + \mu_t^i K_t^i + \pi_t^i), \quad (3.2)$$

where

$$\Phi_i(K_{t+1}^i, K_t^i) = \frac{\phi_i}{2} \left(K_{t+1}^i - K_t^i\right)^2,$$

is the physical capital adjustment cost function for $i = \{T, N, CM\}$, namely tradable, nontradable and commodity sectors, p_t^N is the price of nontradable good, I_t^i is the investment in capital for sector i, d_t^H is the debt position in period t, r_t is the interest rate faced by the economy in international financial markets, μ_t^i, w_t^i and π_t^i are the rental rate of physical capital, wages and profits received from firms on each sector i, respectively.

The stock of capital available for each sector evolves according to the following laws of motion:

$$K_{t+1}^i = (1 - \delta) K_t^i + I_t^i. \quad (3.3)$$

Households choose contingent plans for consumption of tradable goods (c_t^T), nontradable goods (c_t^N), labor supply for each sector (l_t^T, l_t^N, l_t^{CM}), capital stock in the next period for each sector ($K_{t+1}^T, K_{t+1}^N, K_{t+1}^{CM}$) and debt-holdings ($d_t^H$) by maximizing their discounted expected utility (3.1) subject to their budget constrain (3.2), the laws of motion of capital (3.3) for $i = \{T, N, CM\}$, and a non-Ponzi game constraint of the form:

$$\lim_{j \to \infty} \mathrm{E}_t \frac{d_{t+j+1}}{\prod_{s=0}^{j} (1 + r_s)} \leq 0.$$

The Lagrangian associated to households' optimization problem is defined as

$$\mathcal{L} = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ U(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) - \lambda_t [c_t^T + p_t^N c_t^N + \sum_i (K_{t+1}^i - (1-\delta) K_t^i + \Phi(K_{t+1}^i, K_t^i)) + r_{t-1} d_{t-1} - (d_t - d_{t-1}) - \sum_i (w_t^i l_t^i + \mu^i k_t^i + \pi^i)] \Bigg\},$$

where λ_t is the Lagrange multiplier associated to the budget constraint. The optimal conditions associated to the households' problem are (3.2), (3.3) for $i = \{T, N, CM\}$, all holding with equality, and

$$[U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) + \beta\,\mathrm{E}_t(U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}))]A'_{c_t^T}(c_t^T, c_t^N) = \lambda_t, \quad (3.4)$$

$$[U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) + \beta\,\mathrm{E}_t(U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}))]A'_{c_t^N}(c_t^T, c_t^N) = \lambda_t p_t^N, \quad (3.5)$$

$$-U'_{l_t^T}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^T, \quad (3.6)$$

-

$$-U'_{l_t^N}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^N, \quad (3.7)$$

$$-U'_{l_t^{CM}}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^{CM}, \quad (3.8)$$

$$\lambda_t[1 + \Phi'_{K_{t+1}^T}(K_{t+1}^T, K_t^T)] = \beta E_t\{\lambda_{t+1}[(1-\delta) - \Phi'_{K_{t+1}^T}(K_{t+2}^T, K_{t+1}^T) + \mu_{t+1}^T]\}, \quad (3.9)$$

$$\lambda_t[1 + \Phi'_{K_{t+1}^N}(K_{t+1}^N, K_t^N)] = \beta\,\mathrm{E}_t\{\lambda_{t+1}[(1-\delta) - \Phi'_{K_{t+1}^N}(K_{t+2}^N, K_{t+1}^N) + \mu_{t+1}^N]\}, \quad (3.10)$$

$$\lambda_t[1 + \Phi'_{K_{t+1}^{CM}}(K_{t+1}^{CM}, K_t^{CM})] = \beta\,\mathrm{E}_t\{\lambda_{t+1}[(1-\delta) - \Phi'_{K_{t+1}^{CM}}(K_{t+2}^{CM}, K_{t+1}^{CM}) + \mu_{t+1}^{CM}]\}, \quad (3.11)$$

$$\lambda_t = \beta(1 + r_t)\,\mathrm{E}_t\,\lambda_{t+1}, \quad (3.12)$$

where

$$U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \left[c_t - \tau c_{t-1} - \frac{(l_t^T)^{\omega^T}}{\omega^T} - \frac{(l_t^N)^{\omega^N}}{\omega^N} - \frac{(l_t^{CM})^{\omega^C}}{\omega^{CM}}\right]^{-\sigma},$$

$$U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}) = (-\tau)\left[c_{t+1} - \tau c_t - \frac{(l_{t+1}^T)^{\omega^T}}{\omega^T} - \frac{(l_{t+1}^N)^{\omega^N}}{\omega^N} - \frac{(l_{t+1}^{CM})^{\omega^C}}{\omega^{CM}}\right]^{-\sigma},$$

$$U'_{l_t^i}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = -(l_t^i)^{(\omega_i - 1)} \left[c_t - \tau c_{t-1} - \frac{(l_t^T)^{\omega^T}}{\omega^T} - \frac{(l_t^N)^{\omega^N}}{\omega^N} - \frac{(l_t^{CM})^{\omega^C}}{\omega^{CM}} \right]^{-\sigma},$$

$$\Phi'_{K_{t+1}^i}(K_{t+1}^i, K_t^i) = \phi_i(K_{t+1}^i - K_t^i),$$

$$\Phi'_{K_{t+1}^i}(K_{t+2}^i, K_{t+1}^i) = -\phi_i(K_{t+2}^i - K_{t+1}^i),$$

for $i = \{T, N, CM\}$, and

$$A'_{c_t^T}(c_t^T, c_t^N) = \chi \left(\frac{c_t}{c_t^T} \right)^{\frac{1}{\varphi}},$$

$$A'_{c_t^N}(c_t^T, c_t^N) = (1-\chi) \left(\frac{c_t}{c_t^N} \right)^{\frac{1}{\varphi}}.$$

The interpretation of these equations is as follows: equations (3.4)-(3.5) means that in period t households choose how much to consume tradable and nontradable goods such as to equate the expected discounted marginal utility of consumption in period t to the marginal utility of wealth; equations (3.6)-(3.8) states that the households' labor supply for each sector will be set by equating the disutility of labor to the marginal utility value of the wage rate in period t; equations (3.9)-(3.11) define the optimal amount of investment in capital goods; and finally, equation (3.12) is an Euler relation associating the intertemporal rate of substitution in consumption to the interest rate on the international financial asset.

3.1.2 Commodity and Nontradable Sector

Commodity and nontradable goods are produced by means of a production function that takes labor services and physical capital as inputs. As in Neumeyer & Perri (2005), Uribe & Yue (2006) and Shousha (2016), the production process is subject to working capital constraint that requires firms to hold an amount κ^j of a non-interest bearing asset to finance a fraction of the total production factor cost each period. The working capital constraint takes the form

$$\kappa_t^j \geq \eta^j [w_t^j l_t^j + \mu_t^j K_t^j], \tag{3.13}$$

for $j = \{N, CM\}$ and where the parameter $\eta^j \geq 0$ represents the fraction of the total production factor bill that firms must hold.

Commodity and nontradable firms are allowed to borrow from international financial markets at a cost r_t, namely the interest rate faced by the economy in these markets, to finance their expenses with production factors. The profit of the commodity and nontradable firms, denoted by π^j, is given as:

$$\pi_t^j = p^j Y_t^j + (d_t^j - d_{t-1}^j) - w_t^j l_t^j - \mu_t^j K_t^j - (\kappa_t^j - \kappa_{t-1}^j) - r_{t-1} d_{t-1}^j, \tag{3.14}$$

for $j = \{N, CM\}$ and where p_t^j is the price of good j, Y_t^j is the output of good j and d_t^j stands for the debt position of the firm in period t. Let firms' total liabilities (a_t^j) in period t be defined as $a_t^j = (1 + r_t)d_t^j - \kappa_t^j$. Then, the profit of the firms can be rewritten as

$$\pi_t^j = p_t^j Y_t^j + \frac{a_t^j}{1 + r_t} - a_{t-1}^j - w_t^j l_t^j - \mu_t^j K_t^j - \left(\frac{r_t}{1 + r_t}\right) \kappa_t^j, \tag{3.15}$$

We assume the case where the international interest rate is positive at all times, so the working capital constraint will bind in every period. Thus, using (3.13) holding with equality in equation (3.15) to eliminate κ_t^j, we get:

$$\pi_t^j = p_t^j Y_t^j + w_t^j l_t^j \left[1 + \eta^j \left(\frac{r_t}{1 + r_t}\right)\right] + \mu_t^j K_t^j \left[1 + \eta^j \left(\frac{r_t}{1 + r_t}\right)\right] + \frac{a_t^j}{(1 + r_t)} - a_{t-1}^j, \tag{3.16}$$

So, from this last equation it is clear that the introduction of working capital constraint induces a distortion in the marginal cost of production factors that is increasing in the interest rate faced by the economy in the international financial markets.

Assuming that commodity and nontradable goods producers have a Cobb-Douglas technology and a competitive behavior in output and production factor markets, the firms' objective is to choose a_t^j, l_t^j and K_t^j to maximize the present value of the stream of profits discounted using households' marginal utility of wealth, who are the firms owners, subjected to the (flow) budget constraint, to the production technology, and to a non-Ponzi game borrowing constraint. Formally,

$$\text{Max } \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t^j, \tag{3.17}$$

subject to

$$\pi_t^j = p_t^j Y_t^j + w_t^j l_t^j \left[1 + \eta^j \left(\frac{r_t}{1 + r_t}\right)\right] + \mu_t^j K_t^j \left[1 + \eta^j \left(\frac{r_t}{1 + r_t}\right)\right] + \frac{a_t^j}{(1 + r_t)} - a_{t-1}^j, \tag{3.18}$$

$$Y_t^j \leq A_t^j (K_t^j)^{\alpha^j} (l_t^j)^{1-\alpha^j}, \tag{3.19}$$

$$\lim_{m \to \infty} \mathrm{E}_t \frac{a_{t+m+1}^j}{\prod_{s=0}^{m} (1 + r_s)} \leq 0, \tag{3.20}$$

for $j = \{N, CM\}$, where $\alpha^j \in (0,1)$ is the capital share and A_t^j is the productivity factor. The first order conditions associated with K_t^j and l_t^j are, respectively

$$K_t^j = \frac{p_t^j \alpha^j Y_t^j}{\mu_t^j \left[1 + \eta^j \left(\frac{r_t}{1+r_t}\right)\right]}, \tag{3.21}$$

$$l_t^j = \frac{p_t^j (1-\alpha^j) Y_t^j}{w_t^j \left[1 + \eta^j \left(\frac{r_t}{1+r_t}\right)\right]}. \tag{3.22}$$

Regarding the net liabilities, any process a_t^j satisfying equations (3.18) and (3.20) is optimal. Therefore, assuming that firms start with no liabilities, then an optimal plan is holding no liabilities at all times, that is

$$\frac{a_t^j}{1+r_t} = a_{t-1}^j.$$

This fact implies the debt borrowing in period t equals to

$$d_t^j - d_{t-1}^j = r_{t-1} d_{t-1}^j + \eta^j \left[\frac{w_t^j l_t^j + \mu_t^j K_t^j}{1+r_t} - (w_{t-1}^j l_{t-1}^j + \mu_{t-1}^j K_{t-1}^j)\right]. \tag{3.23}$$

Thus, the optimal conditions associated to commodity and nontradable sectors problems' are (3.21), (3.22), (3.23) and (3.19) holding with equality.

3.1.3 Tradable Sector

In addition to capital and labor services, tradable goods are produced by a technology that takes commodity goods as input in its production process. As in commodity and nontradable sector, firms in tradable sector are also subject to a working capital constraint, which states that firms must hold a fraction η^T of its total expending in production factors, namely physical capital, labor and commodity goods, in the form of the non-interest bearing asset κ^T. The working capital for tradable sector takes the form:

$$\kappa_t^T \geq \eta^T [w_t^T l_t^T + \mu_t^T K_t^T + p_t^{CM} CM_t^T].$$

Firms in this sector can also borrow from international financial markets to cover their working capital expenses. Assuming a Cobb-Douglas production function, the firm's problem is to choose contingent plans for physical capital (K_t^T), labor services (l_t^T), commodity goods (CM_t^T) and liabilities (a_t^T) in order to maximize their discounted expected stream of profits, that is:

$$\text{Max } \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t^T, \tag{3.24}$$

subject to

$$\begin{aligned}\pi_t^T =\ & Y_t^T + w_t^T l_t^T \left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right] + \mu_t^T K_t^T \left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right] \\ & + p_t^{CM} CM_t^T \left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right] + \frac{a_t^T}{(1+r_t)} - a_{t-1}^T,\end{aligned} \tag{3.25}$$

$$Y_t^T \leq A_t^T (K_t^T)^{\alpha^T} (CM_t^T)^{\gamma^T} (l_t^T)^{1-\alpha^T-\gamma^T}, \tag{3.26}$$

$$\lim_{m\to\infty} \mathrm{E}_t \frac{a_{t+m+1}^T}{\prod_{s=0}^m (1+r_s)} \leq 0, \tag{3.27}$$

where $\alpha^T, \gamma^T \in (0,1)$ are the capital and commodity share, respectively, A_t^T is the productivity factor and p_t^{CM} is the exogenous price of commodity goods.

Firms in the tradable sector also hires labor and physical capital services from perfectly competitive markets, hence the optimal conditions are similarly given by equation (3.26) holding with equality and

$$K_t^T = \frac{\alpha_T Y_t^T}{\mu_t^T \left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right]}, \tag{3.28}$$

$$CM_t^T = \frac{\gamma^T Y_t^T}{p_t^{CM} \left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right]}, \tag{3.29}$$

$$l_t^T = \frac{(1-\alpha^T-\gamma^T) Y_t^T}{w_t^T \left[1+\eta^T, \left(\frac{r_t}{1+r_t}\right)\right]}, \tag{3.30}$$

$$\begin{aligned} d_t^T - d_{t-1}^T = r_{t-1} d_{t-1}^T + \eta^T \Bigg[& \frac{w_t^T l_t^T + \mu_t^T K_t^T + p_t^{CM} CM_t^T}{1+r_t} \\ & - (w_{t-1}^T l_{t-1}^T + \mu_{t-1}^T K_{t-1}^T + p_{t-1}^{CM} CM_{t-1}^T) \Bigg]. \end{aligned} \tag{3.31}$$

3.1.4 International Capital Markets

We assume that international investors are willing to lend to the economy any amount at the country-specific interest rate r_t. The interest rate faced by the domestic economy (r_t) is the sum of an interest rate for a risk free asset and a country-specific risk premium. To close the model, we follow Schmitt-Grohé & Uribe (2003) and assume a debt-elastic interest rate premium. That is, there is a risk to default on payments to foreign lenders and it is increasing with the debt position relative to its steady state level: the more the aggregate debt position is above its steady state level, the higher is the country-specific interest rate in international financial markets[4]. Moreover, as in Shousha (2016), to capture the co-movements between commodity prices and the country-specific risk premium, we also assume that commodity prices affect the default risk, a result in line with Fernández et al. (2015), which found that periods of high commodity prices coincide with low levels of country spreads. Therefore, the country-specific interest rate in international financial markets is a decreasing function of the position of commodity prices relative to its steady state level and an increasing function of the position of aggregate debt relative to its steady state value:

$$r_t = (1-\rho^r)\overline{r} + \rho^r r_{t-1} + \mathrm{v}^d \left[e^{\left(d_t - \overline{d}\right)} - 1 \right] + \mathrm{v}^C \left[e^{\left(p_t^{CM} - \overline{p}^{CM}\right)} - 1 \right] + \zeta_t^r, \tag{3.32}$$

where ρ^r governs the autoregressive component of the real interest rate, $\overline{r}$ is the steady state level of the country-specific interest rate, d_t is the total debt position of the economy in period t and $\overline{d}$ is its steady state level, $\overline{p}^{CM}$ is the steady state level of commodity price and ζ_t^r is a gaussian disturbance term with mean zero and standard deviation σ^r representing a shock in interest rate process[5].

3.1.5 Exogenous Processes

The commodity price process is assumed to be completely exogenous to the small open economy and follows an autoregressive process. The novel element here is the assumption that the commodity price process features two sources of disturbance: an unanticipated and an anticipated components. The anticipated component is represented by innovations that will be revealed with j periods in advance. We model the commodity price process around its steady state as follows:

$$\log\left(p_t^{CM}\right) = (1-\rho^{CM})\log\left(\overline{p}^{CM}\right) + \rho^{CM}\log\left(p_{t-1}^{CM}\right) + \xi_t^{CM}, \tag{3.33}$$

with

$$\xi_t^{CM} = \varepsilon_t^0 + \sum_j \varepsilon_{t-j}^{news},$$

where ε_t^0 and ε_{t-j}^{news} are assumed to be *i.i.d.* gaussian disturbances with mean zero and standard deviation σ_0^{CM} and σ_{-j}^{news}, respectively. The shock ε_t^0 represents the unanticipated shock realized in period t in commodity price. The shock ε_{t-j}^{news} represents j-period anticipated movement in commodity price process. In other words, ε_{t-j}^{news} is an innovation in commodity price that realizes in period t, but the agents learn, receive the news, in

[4]For simplification, we choose not to model the default decisions as this is out of the scope of this present work.

[5]We do not distinguish between shocks in perceived default risk changes and shocks of preferences of international investors for risky assets as our main focus is the connection between commodity price and interest rates and how this is translated to the economy.

period $t - j$. This way, ε_{t-j}^{news} is contained in the agents' information set in period $t - j$, however its implication on commodity price process will only occur in period t, justifying the possibility of an earlier business cycle as the the agents will adjust their optimal decision to the these innovations (news) received j periods in advance.

Finally, we also formulate a technology process for each sector as a AR(1) process around its steady state with a gaussian disturbance term with mean zero and standard deviation σ^i:

$$\log\left(A_t^i\right) = (1 - \theta^i)\log\left(\overline{A}^i\right) + \theta^i \log\left(A_{t-1}^i\right) + \epsilon_t^i, \tag{3.34}$$

where $\overline{A}^i$ represents the steady state level for productivity factor for $i = \{AT, AN, AC\}$.

Hence, the small open economy is subject to four stochastic processes: one endogenous process for the country-specific interest rate, which responds to commodity price and aggregate debt fluctuations, a exogenous process for commodity price, which are composed by anticipated and unanticipated components, and three exogenous technology processes.

3.1.6 Market Clearing

The market clearing conditions are:

- For Nontradable sector:

$$c_t^N = Y_t^N, \tag{3.35}$$

- For Tradable sector:

$$c_t^T + \sum_i [I_t^i + \Phi^i(K_{t+1}^i, K_t^i)] + tb_t^T = Y_t^T, \tag{3.36}$$

- For Commodity sector:

$$p_t^{CM}(Y_t^{CM} - CM_t^T) = tb_t^{CM}, \tag{3.37}$$

- Aggregate Trade balance:

$$tb_t^T + tb_t^{CM} = tb_t, \tag{3.38}$$

- Aggregate debt position:

$$d_t = d_t^H + d_t^T + d_t^N + d_t^{CM}, \tag{3.39}$$

- Balance of payments:

$$tb_t - r_{t-1}d_{t-1} = -(d_t - d_{t-1}), \tag{3.40}$$

where tb_t^{CM} and tb_t^T are the trade balance for commodity and tradable sector, respectively.

3.1.7 Competitive Equilibrium

Given initial conditions $K_0^T, K_0^N, K_0^{CM}, d_{-1}, A_0^T, A_0^N, A_0^{CM}$, stochastic disturbances ζ_t^r, ξ_t^{CM}, $\epsilon_t^{AT}, \epsilon_t^{AN}, \epsilon_t^{CM}$ and an exogenous commodity price (p_t^{CM}), a competitive equilibrium is a set of sequences for

$$\{c_t^T, c_T^N, K_{t+1}^T, K_{t+1}^N, K_{t+1}^{CM}, I_t^T, I_t^N, I_t^{CM}, l_t^T, l_t^N, l_t^{CM}, d_t, A^T, A^N, A^{CM}, Y_t^T, Y_t^N, Y_t^{CM}, CM_t\}_{t=0}^{\infty},$$

and prices

$$\{\lambda_t, r_t, p_t^N, w_t^T, w_t^N, w_t^{CM}, \mu_t^T, \mu_t^N, \mu_t^{CM}\}_{t=0}^{\infty},$$

such that,

1. The allocations $\{c_t^T, c_T^N, K_{t+1}^T, K_{t+1}^N, K_{t+1}^{CM}, I_t^T, I_t^N, I_t^{CM}, l_t^T, l_t^N, l_t^{CM}, d_t^H\}$ solve the households' problem given prices and the laws of motion of capital.

2. Given the prices, the allocations

   $$\{K_t^T, K_t^N, K_t^{CM}, l_t^T, l_t^N, l_t^{CM}, CM_t^T, d_t^{CM}, d_t^N, d_t^T, A_t^T, A_t^N, A_t^{CM}, Y_t^T, Y_t^N, Y_t^{CM}\}$$

   solve the firms' problem.

3. The market clears for tradable, nontradable and commodity goods, capital, labor, total foreign debt position, trade balance and balance of payments.

3.2 Solution Method and Calibration

The theoretical model is composed by a system of 40 nonlinear equations for 40 endogenous variables with 29 structural parameters. The characterization of the steady state is complex to solve analytically, so we proceed to achieve it numerically. Then, we perform a second order approximation of the system of nonlinear equilibrium conditions around the deterministic steady state and we use the method proposed by Sims (2002) to find the model solution.

We calibrated the structural parameters of the model according to the literature as follows: following Mendoza (1991), we set $\omega_T = \omega_N = \omega_C = 1.455$ and $\sigma = 2$. We set the elasticity of substitution between tradable and nontradable (φ) to 0.5, according to Akinci (2011). We set the depreciation rate at 2.5%, which is a fairly standard value. We set the steady-state interest rate faced by the small open economy in international financial markets at 11% per year, as in Schmitt-Grohé & Uribe (2015), which implies a interest rate of 2.75% per quarter. This value is consistent with an average U.S. interest rate of about 1% and an average country spread of 1.75 percent. We set $\beta = 0.98$. We set the parameter $\overline{d}$ to 0.09 in order to get a steady state value 1% for trade balance-to-output ratio. We set χ is set to 0.35 to have nontradable final goods production-to-output ratio of 50 percent. Following Na (2015), we set $\alpha^{CM} = \alpha^{T} = 0.35$, while $\gamma^{T} = 0.05$. Using the results from Uribe (1997) that calculates the labor share in the nontraded sector to be 0.75, we set $\alpha^{N} = 0.25$, and p^{CM} to 0.69 according to Shousha (2016) in order to induce a steady-state value of 10% of commodity exports-to-output ratio.

The remaining parameter is set according to the estimations obtained by Shousha (2016) as follows: $\tau = 0.45$; $\phi^{T} = 4.6$, $\phi^{N} = 9.3$; $\phi^{CM} = 10.3$ $\eta^{T} = 1.9$; $\eta^{N} = 2.1$;$\eta^{CM} = 2.5$; $\rho^{r} = 0.9$, $\rho^{CM} = 0.9$; $\theta^{N} = 0.88$; $\theta^{CM} = 0.87$; $\theta^{T} = 0.89$; $\upsilon^{d} = 0.077$; $\upsilon^{C} = -0.014$, according to his estimates. The following table summarizes the calibration of the parameters.

Table 1: Calibrated parameter values

Parameter	Value	Source
Frisch elasticity of labor supply	$\omega_T = \omega_N = \omega_{CM} = 1.455$	Mendoza (1991)
Relative Risk aversion	$\sigma = 2$	Mendoza (1991)
Steady State P^{CM}	$p^{CM} = 0.69$	Shousha (2016)
Elasticity of substitution	$\varphi = 0.5$	Akinci (2011)
Depreciation rate	$\delta = 0.025$	Standard value
Interest rate	$\overline{r} = 0.0275$	Schmitt-Grohé & Uribe (2015)
Discount factor	$\beta = 0.98$	$\beta = 1/(1+\overline{r})$
Steady state foreign debt	$\overline{d} = 0.09$	TB-to-output ratio = 1%
Capital share ratio	$\alpha^{T} = \alpha^{CM} = 0.35$	Na (2015)
Capital share ratio	$\alpha^{N} = 0.25$	Uribe (1997)
Commodity input share	$\gamma^{T} = 0.05$	Commodity inputs = 5%
Consumption basket parameter	$\chi = 0.35$	Share of nontradable output = 50%
Capital adjustment parameter	$\phi^{T} = 4.6$	Shousha (2016)
Capital adjustment parameter	$\phi^{N} = 9.3$	Shousha (2016)
Capital adjustment parameter	$\phi^{CM} = 10.3$	Shousha (2016)
Working capital parameter	$\eta^{T} = 1.9$	Shousha (2016)
Working capital parameter	$\eta^{N} = 2.1$	Shousha (2016)
Working capital parameter	$\eta^{CM} = 2.5$	Shousha (2016)
Degree of internal habit	$\tau = 0.45$	Shousha (2016)
Parameter of interest rate process	$\upsilon^{d} = 0.077$	Shousha (2016)
Parameter of interest rate process	$\upsilon^{C} = -0.014$	Shousha (2016)
AR(1) coefficient of p^{CM} process	$\rho^{CM} = 0.9$	Shousha (2016)
AR(1) coefficient of r process	$\rho^{r} = 0.9$	Shousha (2016)
AR(1) coefficient of A^{N} process	$\theta^{N} = 0.88$	Shousha (2016)
AR(1) coefficient of A^{T} process	$\theta^{T} = 0.89$	Shousha (2016)
AR(1) coefficient of A^{CM} process	$\theta^{CM} = 0.87$	Shousha (2016)

Note: The parameters were calibrated with values from the related literature concerning emerging economies.

CHAPTER 4

Analysis

In this section, we will analyze the properties of the model in generating adequate responses of the economic system to exogenous shocks, namely unanticipated commodity prices, international interest rate and TFP shocks. To this end, we will assess the impulse response functions (IRF) and see how the main aggregate variables behave. Our inspection begins by analyzing a formulation with only one real rigidity, namely capital adjustment cost, and evaluate how this economy model behaves regarding unexpected exogenous shocks. Formally, we will analyze a version of the presented small open economy model setting $\tau = 0$ (internal habit formation parameter), $\eta^T = \eta^N = \eta^{CM} = 0$ (working capital constraint parameters) and not allowing the firms to borrow from international financial markets. We call this formulation the reduced model. Thereafter, we will analyze the presented model with three real rigidities (capital adjustment cost, internal habit formation and working capital constraint), which we call the baseline model, and evaluate if the introduction of these aspects can help the model in generating suitable responses according to the literature regarding these exogenous shocks. Thereon, once we validate that the baseline model engenders decent responses from the considered unanticipated shocks, we will investigate how this small open economy model would behave in an environment where the commodity price process features an anticipated component that can be triggered with releases of news about future changes in the commodity prices.

Finally, we will assess the forecast error variance decomposition to evaluate the importance of anticipated shocks in accounting for business cycles in this economic model design.

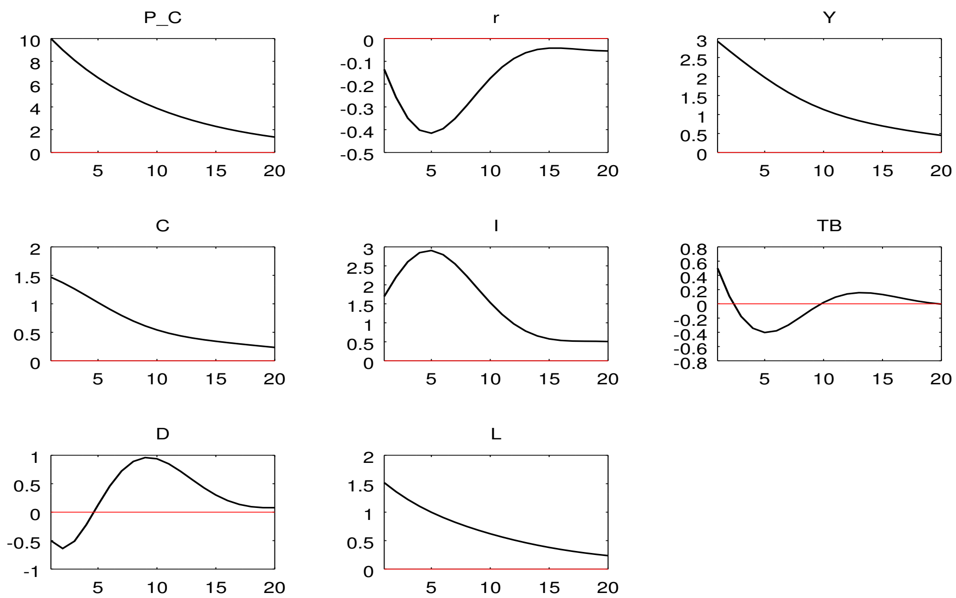
4.1 Reduced Model

Our analysis begins with what we call reduced model, which is the earlier presented model, but with only one real rigidity: capital adjustment cost. This model formulation is similar to the one used in Schmitt-Grohé & Uribe (2015) and Zeev et al. (2016).

4.1.1 Unexpected Commodity Price Shock

Figure 4.1 shows the behavior of the main aggregate variables in the reduced model regarding a shock of 10% in commodity price process.

Figure 4.1: IRF of the reduced model to an unanticipated 10% commodity price shock.



Notes: Author's calculation. P_C, r, Y, C, I, TB, D and L stand for commodity price, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

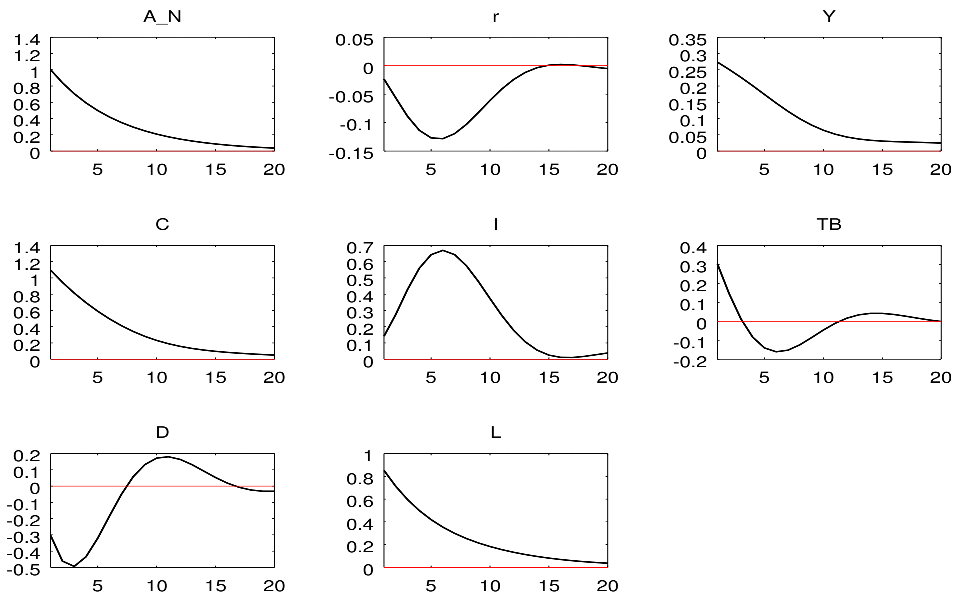
As we can see, an increase in commodity price leads to an improvement in the output, investment, consumption, and trade balance. The explanation behind this has to do with the spillover effect. A surge in commodity price increases the revenue of the commodity sector, which will respond to it increasing the demand for capital and labor services to raise its production. This boost in the demand for production factors in the commodity sector will induce a raise in wage and capital rents, leading to a favorable effect in households' income, who will respond increasing the consumption for all goods (tradable and nontradable), investment, and reducing the borrowing from abroad. The trade balance initially display a small improvement, as a result of the improvement in trade balance for the commodity sector, followed by a deterioration. This later deterioration in trade balance is explained by the fall in trade balance for tradable sector, as the production for tradable sector reduces due to higher cost in commodity goods, which are used as inputs in the production process.

These results are partially in line with what was found in Silva (2011) and Shousha (2016), as in their work trade balance display an improvement after a commodity price shock. Now we will analyze how the reduced model behaves when it experiences productivity shocks in each sector.

4.1.2 Total Factor Productivity Shock

Figures 4.2-4.4 show the impulse response functions of the reduced model to 1% TFP shock in each sector.

Figure 4.2: IRF of the reduced model to 1% shock TFP for nontradable sector.

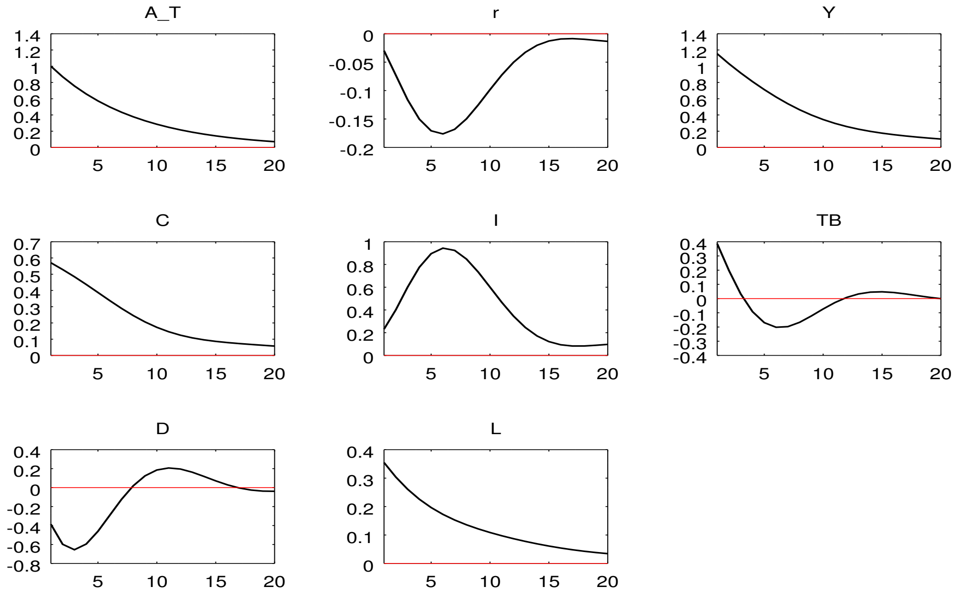


Notes: Author's calculation. A_N, r, Y, C, I, TB, D and L stand for nontradable TFP, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

The impulse response functions show that a shock in productivity in each sector display positive effects on output, consumption, investment, trade balance and hours worked. The mechanism is explained as follows: a favorable shock in productivity will generate an increase in the demand for capital and labor services and lead to a surge in production in each sector. This increase in demand for production factors will induce a raise in wage and capital rents, which will reflect an improvement in households' income, explaining the fall in international borrowings. Also, this boost in households' income produces a positive income effect that causes an increase in the demand for consumption and investment goods.

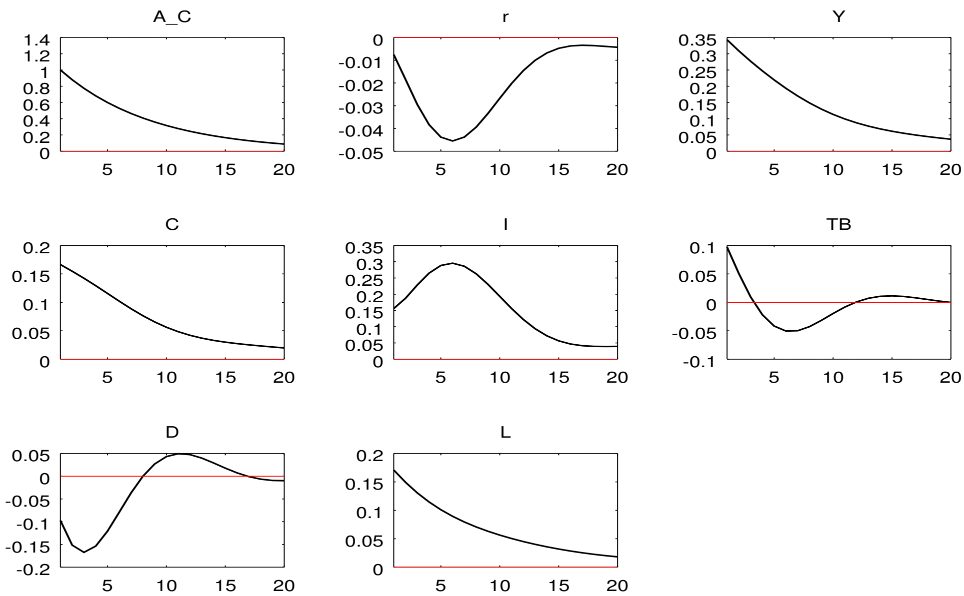
These responses of the reduced model regarding productivity shocks are in line with the responses generated by standard real business cycle model as in Mendoza (1991) and

Figure 4.3: IRF of the reduced model to 1% shock in TFP for tradable sector.



Notes: Author's calculation. A_T, r, Y, C, I, TB, D and L stand for tradable TFP, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

Figure 4.4: IRF of the reduced model to 1% shock in TFP for commodity sector.



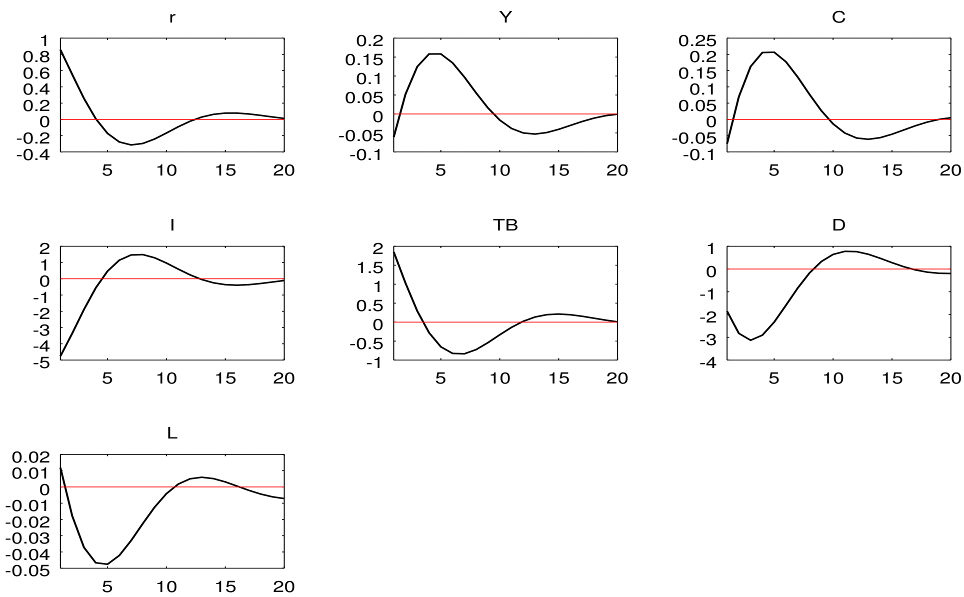
Notes: Author's calculation. A_C, r, Y, C, I, TB, D and L stand for commodity TFP, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

Kose (2002). Now we proceed and evaluate how this model behaves in response to a international interest rate shock.

4.1.3 International Interest Rate Shock

Figure 4.5 shows how the reduced model responds to 1% shock in the international interest rate. An important point to emphasize is that we do not distinguish innovations in interest rate process as coming from changes in investors preferences or from changes in the risk free interest rate, as this is out of the scope of this present exercise. Our objective here is to assess how a change in international financial conditions could affect the economic system.

Figure 4.5: IRF of the reduced model to 1% shock in international interest rate.



Notes: Author's calculation. r, Y, C, I, TB, D and L stand for international interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

The impulse response functions show that an international interest rate shock will lead to an initial decrease in output and consumption followed by a surge in both aggregate variables. However, these results are not supported by the literature. For example, Neumeyer & Perri (2005), Uribe & Yue (2006) and Shousha (2016) showed empirically and theoretically that, after an international interest rate shock, emerging economies display a reduction in both output and consumption. This is an important issue as we are trying to consider the effects of commodity price on international interest rate as a source of amplification of commodity price shocks, and since the reduced model failed to generate reasonable responses regarding the interest rate shock, this caveat could compromised this channel.

Hence, we can reckon that the reduced model is not appropriate to generate adequate responses according to literature, as this particular design model with only one real rigidity failed in replicating adequate effects of an international interest rate shock on the economy model.

4.2 Baseline Model

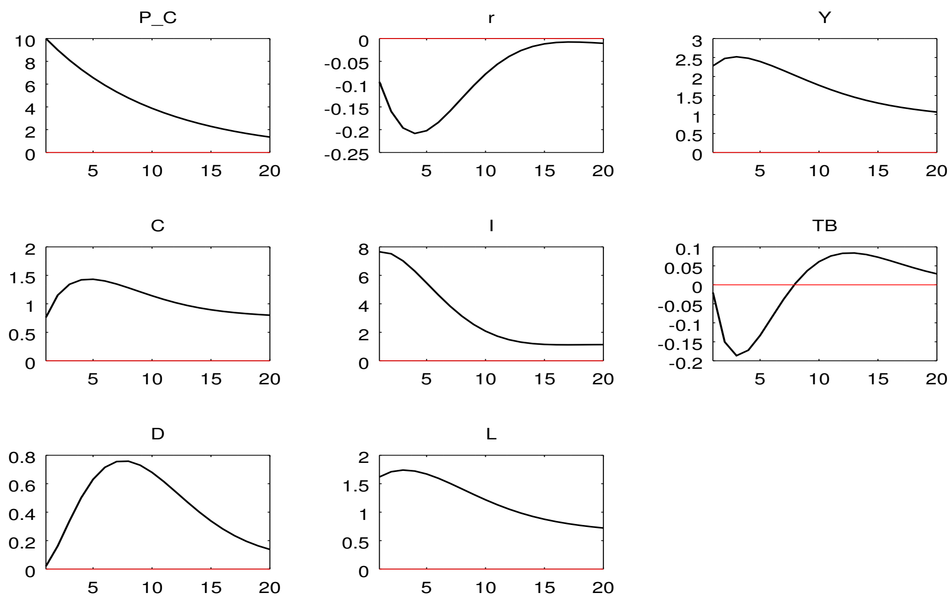
Now we will analyze the ability of the baseline model in generating plausible responses according to the literature regarding unexpected shocks, namely commodity price, productivity and international interest rate shocks. As stated before, this model design features three real rigidities: capital adjustment cost, internal habit formation in consumption and working capital constraint.

We add internal habit formation with the purpose of trying to reproduce the hump-shaped response of consumption to expansionary shocks, which is hard to replicate in the absence of this feature. We also include working capital constraint for firms and also allow them to borrow from international markets. This feature induces a direct effect of international interest rate on firms, as it influences the marginal production factors cost, and improves the ability of the model in replicating a more realistic response of output to international interest rate shocks.

4.2.1 Unexpected Commodity Price Shocks

Figure 4.6 shows the response of the baseline model to a 10% unexpected increase in the exogenous commodity price. As we can see, the surge in commodity price lead to an improvement in output, consumption, investment and hours worked, whereas the trade balance deteriorates initially and then displays a rise.

Figure 4.6: IRF of the baseline model to an unanticipated 10% commodity price shock.



Notes: Author's calculation. P_C, r, Y, C, I, TB, D and L stand for commodity price, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

The explanation behind this starts with the spillover effect. Figures A.1-A.4 shows that after a favorable unexpected shock in commodity price, the revenues in the commodity sector will display an increase, which will induce a rise in the demand for capital, labor services and production. However, this raise in commodity price also will have a negative impact on tradable sector, as commodity goods are used as inputs in this sector and its demand reduces due to the higher price. This incremental cost in the tradable sector will decrease the demand for labor services, as well as commodity goods, generating a decline in production. Although the decrease in the production of tradable goods causes a decrease in labor demand, the wage rate rises as to balance the outflow of labor services to other sectors. The boost in wage and capital rents from commodity sector will improve households' income, which will lead to a rising in consumption of tradable, nontradable and investment goods. As a result of this rising in consumption of nontradable goods, there is a positive response on its price. This effect will induce an increase in the demand for labor, capital services and, consequently, production for nontradable sector, which will also increasing the rate of return of these production factors.

On the trade balance side, as the consumption of tradable, investment goods increase and the production in tradable sector reduces, the trade balance for this sector deteriorates. Also, as the production of commodity rises and the demand for commodity goods from the tradable sector decreases, the trade balance in this sector enlarges. As the total trade balance is the sum of trade balance of tradable and commodity sector, then the total trade balance reduces initially due to the higher declining of the trade balance for tradable goods regarding the rising of the trade balance for commodity goods. This is explained, in the context of the baseline model, with the high response of investment to the exogenous shock in commodity price. As tradable goods are used as for consumption and investment goods, the increase in the consumption, the high raise in investment goods combined with the decrease in production of tradable goods generates this high contraction in trade balance for tradable sector, which induces to this initial lessening in total trade balance.

Regarding debt holdings, as the demand for capital and labor services increase in the nontradable and commodity sectors, their foreign debt positions increase due to working capital constraint. On the other hand, in the tradable sector, as the labor and commodity demand fall, the foreign debt holding for this sector decreases. For households, as there is an improvement in income, with the increment in wage and capital rents, the foreign debt position reduces. The total foreign debt is the sum of debt for each sector and households, and as the raise in debt position for nontradable sector and commodity sector is greater than the reduction on this matter for tradable sector and households, the total debt position increases in response of a unexpected positive commodity price shock. Finally, at the same time, a further amplification channel operates through a favorable response from the interest rate faced by the economy in international financial markets triggered by the positive shock in commodity price that will induce a direct effect on firms.

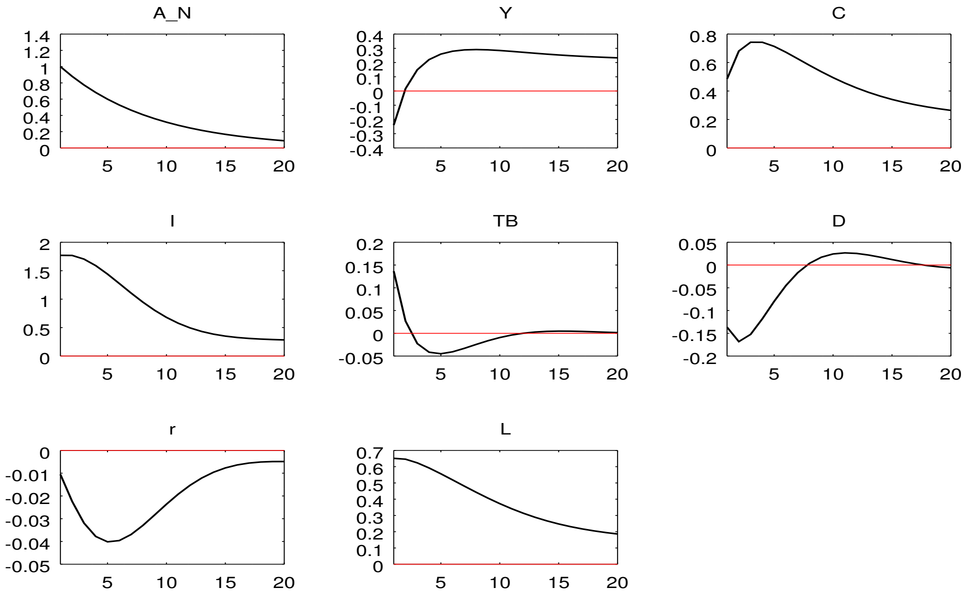
These results (improvement in output, consumption, investment and hours worked) are qualitatively in line with what was found empirically in Silva (2011), Fornero et al.

(2016), Schmitt-Grohé & Uribe (2015), Fernández et al. (2015) and Shousha (2016) for emerging economies.

4.2.2 Total Factor Productivity Shock

The Figures 4.7-4.9 depict the impulse response functions of a 1% positive shock in TFP in each sector. The small open economy model predicts that, in general, a favorable productivity factor shock will display positive responses from output, consumption, investment, trade balance and a reduction in the foreign borrowing.

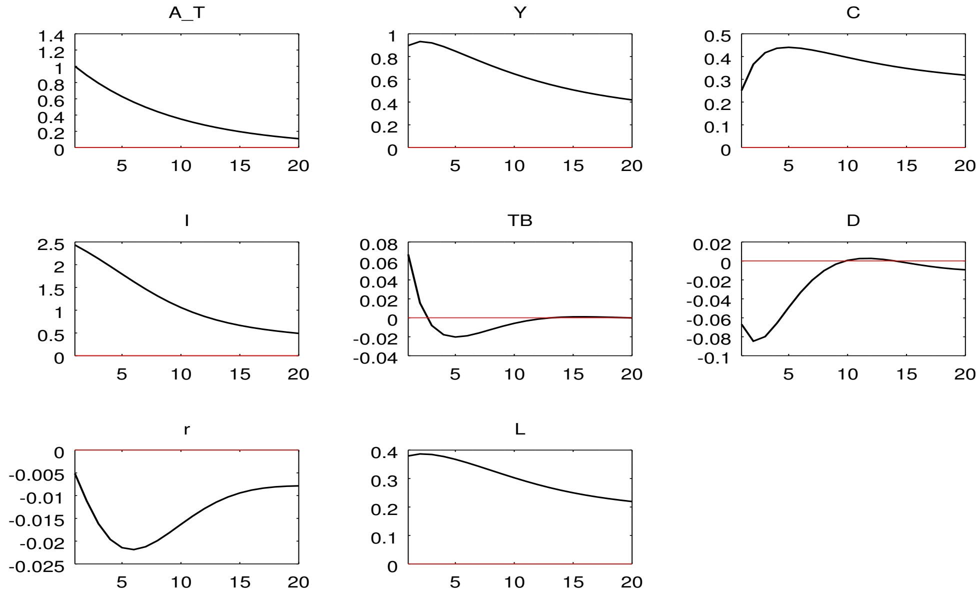
Figure 4.7: IRF of the baseline model to 1% shock in TFP for nontradable sector.



Notes: Author's calculation. A_N, Y, C, I, TB, D, r and L stand for nontradable TFP, aggregate output, consumption, investment, trade balance, foreign debt, interest rate and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

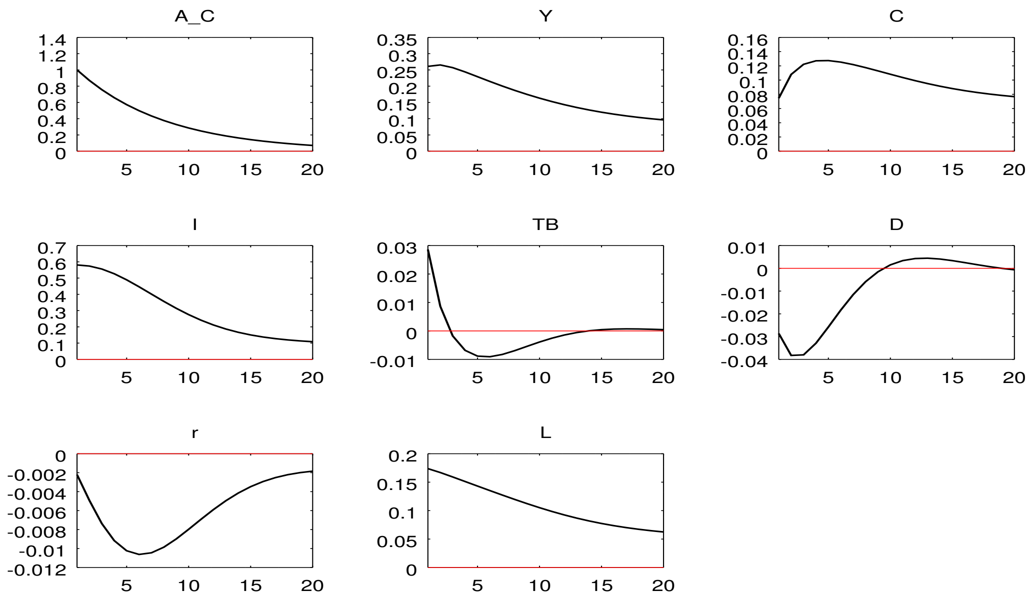
In Figure 4.7, an important issue to note is the initial fall in the output. This is explained as the total output is defined in terms of numeraire tradable goods. Thus, the value nontradable production in terms of numeraire good ($p_t^N Y_t^N$) decreases more than the improvement in total output due to the bigger initial fall of nontradable price. As the production of nontradable begins to respond more strongly, the total output displays an improvement.

Figure 4.8: IRF of the baseline model to 1% shock in TFP for tradable sector.



Notes: Author's calculation. A_T, r, Y, C, I, TB, D and L stand for tradable TFP, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

Figure 4.9: IRF of the baseline model to 1% shock in TFP for commodity sector.



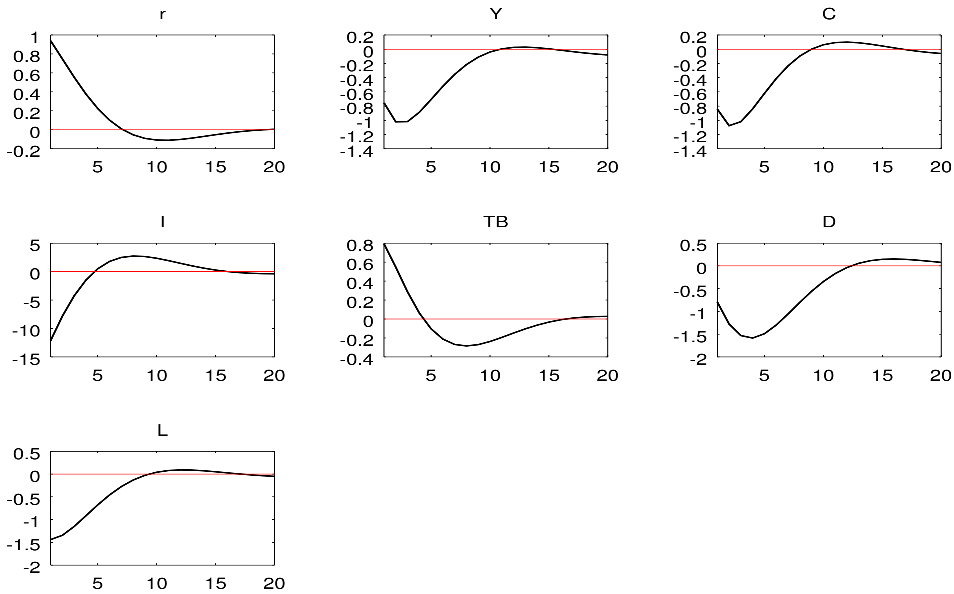
Notes: Author's calculation. A_C, Y, C, I, TB, D, r and L stand for commodity TFP, aggregate output, consumption, investment, trade balance, foreign debt, interest rate and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

A shock in productivity will display similar responses as in the standard real business cycle models (see Mendoza (1991), Kose (2002)). A favorable shock in productivity in the respective sector will lead to an increase in production factors that will induce a boost in wage rates and capital rents. These facts will generate a positive effect in households' income that will be reflected in an expansion in consumption and investment. The debt position displays a decline that will lead to a lessen interest rate faced by the economy, which will strengthen the favorable cycle in the economy model.

4.2.3 International Interest Rate shock

Figure 4.10 shows how the economic system behaves to 1% shock in the interest rate faced by the small open economy in international markets. As stated before, we do not distinguish innovations in interest rate process as coming from changes in investors preferences or from changes in the risk free interest rate. Our main objective is to assess the ability of the economic model in replicating suitable responses regarding this exogenous shock.

Figure 4.10: IRF of the baseline model to 1% shock in international interest rate.



Notes: Author's calculation. r, Y, C, I, TB, D and L stand for international interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked, respectively. All variables are expressed in percent deviations from their steady state levels.

The impulse response functions show that a non-favorable 1% shock in the interest rate faced by the economy in international financial markets produces a negative impact in the output, consumption and investment. Moreover, there is an improvement in trade balance and a reduction in total foreign debt position and hours worked. These results concur qualitatively with Uribe & Yue (2006), Shousha (2016), which empirically displayed similar responses regarding these variables, and also with Neumeyer & Perri (2005), who found similar responses in the context of a dynamic stochastic general equilibrium for emerging economies.

The introduction of working capital constraint introduces a wedge that distorts the marginal cost of production. This distortion is higher, the higher the cost of holding working capital, which is an increasing function of interest rate faced by the economy in international markets. This way, the surge in the international interest rate leads to a decrease in the the demand for these production factors, which will cause a fall in wage, capital rents and production for all sector. For households, the reduction in wage and capital rents will generate a negative effect on their income, reducing the consumption and investment. The trade balance for tradable sector displays an improvement, as the fall in the domestic absorption (for consumption and investment) is higher than its production. For commodity sector, its trade balance shows a slight reduction. Thus, the total trade balance displays an improvement. Further, the reduction in the demand of production factor by firms will reflect in a decrease in their amount of foreign borrowing, which will lead to the fall in the total debt position.

So, as we can see from impulse response functions 4.6-4.9, the baseline model does a better job than the reduced model in generating adequate macroeconomic dynamics regarding exogenous shocks extensively explored in the literature of business cycles, although the baseline model failed to replicate the improvement in trade balance in response to an unexpected commodity price shock. As a last comparison exercise between these two formulations, we will analyze how these models perform when confronted with data about business cycle statistics in emerging economies. Table 2 reports business cycle statistics for a sample of emerging economies and the same statistics generated by baseline and reduced models.

Table 2: Business cycles statistics for emerging economies

	Data		**Baseline model**		**Reduced model**	
	$\rho(X_t, p_t^{CM})$	$\rho(X_t, Y_t)$	$\rho(X_t, p_t^{CM})$	$\rho(X_t, Y_t)$	$\rho(X_t, p_t^{CM})$	$\rho(X_t, Y_t)$
Y_t	0.50	1.00	0.48	1.00	0.62	1.00
I_t	0.44	0.82	0.50	0.79	0.51	0.77
TBy_t	0.18	-0.40	-0.12	-0.13	-0.03	-0.0004
p_t^{CM}	1.00	0.50	1.00	0.49	1.00	0.62
r_t	-0.23	-0.23	-0.30	-0.42	-0.40	-0.64

Source: Shousha (2016). The data are the simple average of the indicators for the emerging economies (Argentina, Brazil, Chile, Colombia, Peru and South Africa). The data are sampled quarterly from 1994.Q1-2013.Q4. Y, I, TBy, p^{CM} and r denote detrended output, investment, trade balance-to-gdp ratio, export commodity price and country-specific interest rate. Columns labeled baseline model and reduced model report the statistics generated by the respective models.

The results from the table above confirm that the baseline model performs better than the reduced model in replicating reasonable business cycle statistics associated with emerging economies, nonetheless the baseline model also fails to replicate the positive correlation between trade balance and commodity price. Despite this caveat, the baseline model depicts a fairly accurate business cycles statistics. Now we will proceed with the analysis using the baseline model and we will assess the role of news shocks in generating business cycles.

4.3 The Role of News Shocks

Now we will investigate how the baseline model behaves in an environment where exogenous commodity price process features both the unexpected and an anticipated component. As stated before, the anticipated component is characterized as the sum of two signals received four and two period in advance by the agents about a innovation that will occur in period t. We assume that the unexpected shock is lager than the anticipated component in the economy. As in Schmitt-Grohé & Uribe (2012), we assume the variance of the unexpected shock is 75 percent of the total variance of both anticipated and surprise component. Formally,

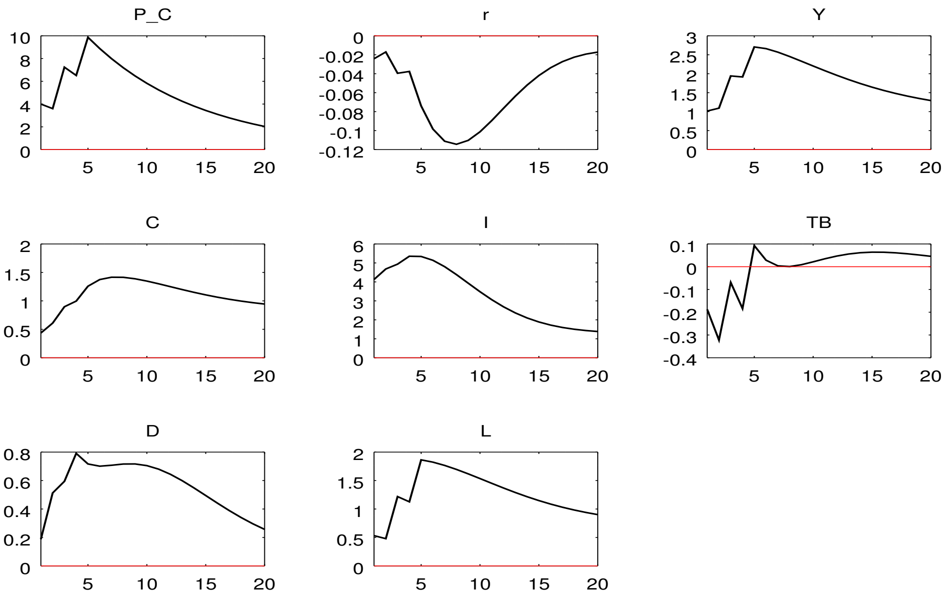
$$\frac{(\sigma_{\varepsilon}^{(0)})^2}{(\sigma_{\varepsilon}^{(0)})^2 + (\sigma_{news}^{(-2)})^2 + (\sigma_{news}^{(-4)})^2} = 0.75,$$

where $\sigma^{(0)}$, $\sigma^{(-2)}$ and $\sigma^{(-4)}$ are the standard deviations of the shocks in periods t, $t-2$, $t-4$, respectively. As in previous analysis, we will consider a 10 percentage point shock in the unanticipated component of the commodity price process. This makes each anticipated component representing a minor shock of around 4%. Hence, this formulation can be summarized as follows: with four quarters in advance, the theoretical small open economy receives a first news about a future change in commodity price. This first signal is personified as a anticipated shock representing a fraction of the future change (10% shock) in the commodity price. After two quarters since the first signal, the economy receives another indicative of this future change in the exogenous process that is also revealed as lesser shock. Then, after four quarters since the first signal the economy model experiences the 10% change in commodity price relative to its steady state level. However, this unexpected shock might play a lower role to account for business cycles, as part of this change was anticipated by the agents.

Figure 4.11 shows how the small open economy model behaves in an environment where agents are able to anticipate future movements in commodity prices from news.

This change in the commodity price triggers movements inside the economy by changing the effective cost of production factors. For instance, as we can see in Figures A.5-A.8, in the commodity sector, this news shock generates an increase in the demand for labor and capital services, which will boost wages and capital rents in the sector. Moreover, these facts will spawn a favorable increase in households' income, as a result of larger wage and capital rents, provoking a rise in consumption of tradable and nontradable goods, investment in physical capital and a decline in borrowing. The rising of consumption of nontradable goods cause an increment in its price, generating a boost on the demand for labor and capital services in this sector. These raises in labor and capital demand in commodity and nontradable sectors also will increase the borrowing from abroad, generating an expansion in debt position for these sectors. The tradable sector will experience a fall in the commodity goods demand. This fact will reflect a reduction in production, which will lead to a lessen labor and capital services demand in the tradable sector. As a result, the demand for working capital will decrease, causing a contraction in debt position for the tradable sector. All these facts together illustrate the initial increase in total foreign debt position, as the increase in borrowing from commodity and nontradable sector is lager than the decrease in the same variable from households and tradable sector.

Figure 4.11: IRF of the baseline model to anticipated shocks in commodity price.



Notes: Author's calculation. P_C, r, Y, C, I, TB, D and L stand for commodity price, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked. All variables are expressed in percent deviations from their steady state levels.

Another important issue to note is that the trade balance depicts a initial fall in the trade balance, as a result of the greater deterioration in production in the tradable sector relative to the improvement in the commodity sector. This fact is illustrated in Zeev et al. (2016) in their empirical analysis for Brazil of terms of trade (TOT) news shocks, although the theoretical model used by them failed to replicate this result for the same country. This caveat might be related to the fact that in their work, the model used is similar to our reduced formulation, which we showed that failed to generate adequate dynamics regarding the effects of changes in international interest rate on the economy model.

Now in order to evaluate how important the anticipated components in commodity prices shock are to account for business cycles in the model we perform the forecast error variance decomposition (FEVD) of the main aggregate variables, namely output, investment, consumption, trade balance and hours worked. The results are summarized in table 3:

Table 3: FEVD for unanticipated and anticipated shocks in commodity price.

Variable	Unanticipated Shock	Anticipated Shock
Output	26.78	32.00
Consumption	21.87	26.38
Total Investment	23.15	21.32
Trade Balance	7.65	10.47
Hours worked	26.46	31.34

Source: Authors' calculation. The results in the table are expressed as a percentage point of the corresponding unconditional variance implied by the model.

The results show that news or anticipated shocks help to account for about 32% of output fluctuation and hours worked, whereas the unexpected commodity price shock accounts for around 27% for the same variables. Moreover, for each of the main aggregate variables in the model, the release of news were equal or even more important in explaining business cycle fluctuation than unanticipated shocks. These result are in line with what was found in Schmitt-Grohé & Uribe (2012) and Zeev et al. (2016), who also showed that news shocks are important source in explaining fluctuation in emerging economies.

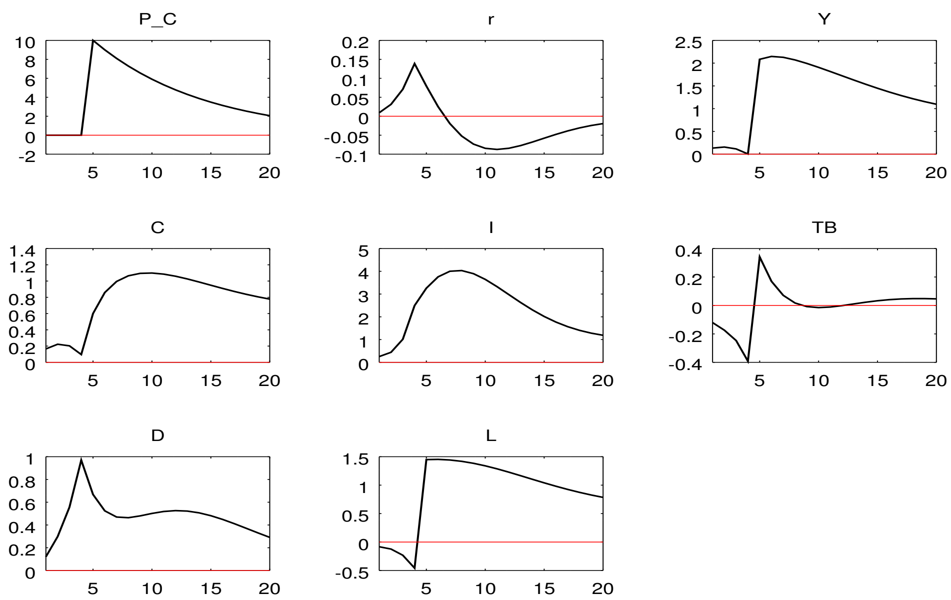
Thus, the theoretical model suggests that the anticipated shocks can be an important source of business cycles for emerging economies, as they are able to generate dynamics in the economic system before the fundamental shock itself is revealed. This is an important result as existing literature on the sources of business cycles implicitly assumes that the totality of aggregate fluctuations regarding commodity price shocks is due to unanticipated changes in this fundamental (Silva, 2011; Fernández et al., 2015; Shousha, 2016). Our exercise shows that, in the context of the presented model, anticipated shocks in commodity prices might play a significant role to account for business cycles in emerging economies.

4.4 Alternative News Shocks

In this section we evaluate a different formulation of how news about future changes in fundamentals could account for business cycle in the economy model. In particular, we will assess an environment where a "pure" news emerges without generating a change in current commodity prices. The novel element here is that differently from the earlier formulation, this "pure" news would affect the economic system only by changing the agents' expectation about the future and not the current fundamental itself. In this sense, the business cycles generated from this "pure" news formulation are what is known in the literature as "Pigou cycles", which states that booms and bust in a economy might arise as the result of overly optimistic or pessimistic expectation about future fundamentals. This formulation of news was explored in Beaudry & Portier (2004), Beaudry et al. (2011) and Miyamoto & Nguyen (2014).

This alternative formulation is described as follows: in period t news about a future shock in commodity price will emanates "from heaven" to the small open economy model. The agents will learn about this news and will adjust their optimal decisions. Then, in period $t+j$ the shock will be revealed to the economy. As before, for comparison purposes, we will assume that a 10% shock will strike the commodity price process four quarters later. Figure 4.12 reports the dynamics associated with the release of the news combined with the realization of the fundamental shock. The release of the news will display an initial positive effect in consumption, investment and a slight positive effect in output. Also, the debt position will increase, explaining the increase in the interest rate faced by the economy in international financial markets, and the trade balance displays a reduction.

Figure 4.12: IRF of the baseline model to an expected 10% shock in commodity price.



Notes: Author's calculation. P_C, r, Y, C, I, TB, D and L stand for commodity price, interest rate, aggregate output, consumption, investment, trade balance, foreign debt and hours worked. All variables are expressed in percent deviations from their steady state levels.

These results are explained as follows: Figures A.9-A.12 show that, for households, these news will lead to a decrease in investment on capital for the tradable sector, as they choose how much to invest based on the discounted expected rate of return on physical capital. This change in investment will alter the capital stock for the tradable sector and, therefore, its production. The fall in tradable production will induce a decrease in demand for labor services, albeit the wage rate will display an improvement as to balance the outflow of labor to nontradable sector. Additionally, the trade balance and the foreign debt position for tradable sector reduces due to the fall in labor and capital services demand. On the other hand, for the nontradable sector, there is an improvement in production as a result of an increase in available physical capital, a consequence of the increase in investment on physical capital for this sector by households. This fact will lead to an increase in the demand for labor services by the nontradable firms, which will also lead to a raise in wage rate, and as a result, the foreign debt position for this sector will also display an increment. All these facts together (increase in wage from tradable and nontradable sector) will induce a positive impact in households' income that will contribute to an increase in consumption of tradable and nontradable goods that will induce the rising in the price of nontradable goods. The total foreign debt position will display an increasing path as a result of the accelerated growth in foreign debt from households and nontradable than the fall in the tradable foreign debt position. This fact explains the rising in the interest rate in international markets, which will, consequently, reinforcing the cycle.

So, according to previously results, the theoretical model structure suggests that a "pure" news may trigger some dynamic in the economy before the commodity price itself displays a change from its steady state level mostly by changing the amount of capital that is accumulated before the shock materializes, a result also urged in Jaimovich & Rebelo (2009). In order to evaluate the importance of this news formulation we perform a FEVD, which the results are summarized in the following table:

Table 4: FEVD for unexpected and expected commodity price shock.

Variable	Unexpected commodity price	Expected Commodity Price
Output	30.37	22.88
Consumption	24.43	17.77
Total Investment	25.52	13.29
Trade Balance	6.98	18.36
Hours Worked	29.60	23.19

Source: Authors' calculation. The results in the table are expressed as a percentage point of the corresponding unconditional variance implied by the model.

Table 4 presents the contribution of an unexpected and expected commodity price shock in explaining aggregate fluctuation in the economy model. As we can see from these results, the news about a future change in commodity price can account around 23% of the output fluctuation and hours worked, whereas when the change in commodity price is not expected, this last shock could account for almost 30% of fluctuation in the same variables. Also, for all aggregate variables, but trade balance, considered in the analysis the contribution of the news to generate business cycles in the model is smaller than that of the unexpected commodity price shock. In other words, although news about a future change in commodity price can trigger fluctuation in investment and labor today, this news play a minor role in accounting for business cycles than when the commodity price shock is not expected.

This is an important result to consider. It shows that, in the context of the model presented here, in an environment where agents are forward-looking and "pure" news about a future change in commodity price are revealed to the economy, this news plays a negligible role in explaining fluctuation before the shock materializes. This result is in line with what was found in Miyamoto & Nguyen (2014), who showed that news shocks cannot be a main driver of business cycles and play a negligible role in explaining business cycles in periods before the fundamental shock materializes.

CHAPTER 5

Conclusion

The literature about business cycles in small open economies always indicates that external changes as commodity price, risk premium and international world interest rate shocks are key drivers in explaining the business cycles in these countries. Mostly, the literature so far are based on the importance of unanticipated shocks to demonstrate this fact. A branch in the literature has focused in theories of expectation-driven business cycles, in particular the effects of news shocks, which are defined as signals about of future changes in fundamentals that might drive the cycles.

In this work we presented a theoretical small open economy model with three real rigidities, namely internal habit formation, capital adjustment cost and working capital constraint, in order to assess the importance of news shocks in accounting for business cycles in emerging economies. The fundamental behind this hypothesis is that in a environment in which agents are forward-looking, news about future changes in exogenous process, such as commodity price, could play a role in generating dynamics in aggregate variables. Calibrating the structural parameters of the model with parameters from the related literature in order to resemble dynamics in emerging economies, we first evaluate the plausibility of the model in generating plausible responses according to the literature from exogenous shocks, such as commodity price, interest rate and productivity shocks, and then we analyze the effects of news shocks in the economic system.

Our main finding is that, in the context of the theoretical model presented here, news shocks in commodity price can be a non-negligible driver of business cycles in emerging economies, accounting for around 32% of the variation output and hours worked in the model, a result in line with what was found in Schmitt-Grohé & Uribe (2012) and Zeev et al. (2016). This result, however, demands an implicitly assumption that news about some future change in commodity price can affect the current commodity price level in a small fraction. We then extend our analysis by asking how a "pure" news could generate fluctuation in the economy without affecting the current fundamental itself. We define "pure" news as a signal that emanates to the small open economy model and does not influence the current commodity price level. In other words, we analyze an alternative news formulation, in which the fluctuation generated could only be emerged from changes in agents expectation, a subject known as "Pigou cycles" in the macroeconomic literature. We found that, in the context of the model presented here, although this "pure" news formulation could trigger fluctuations in some aggregate variables in the current period, especially investment, it plays a minor role in accounting for business cycles, a result in line with Miyamoto & Nguyen (2014), who showed that news shocks played a negligible role in accounting for business cycles before the expected shock materializes.

For future work, we will perform estimation of the structural parameters of the model using Bayesian methods and we will expand the analysis for advanced economies in order to evaluate if anticipated shocks can play a significant role in explaining the business cycles for these countries. Also, there are some other dimensions in which this analyzes could be expanded. We do not account for the case when a "pure" news is revealed, but the fundamental shock does not materialize. This issue is in the heart of "Pigou cycles", which states that cycles in a economy might be triggered as a result of agents' difficulties to properly forecast the future of the economy.

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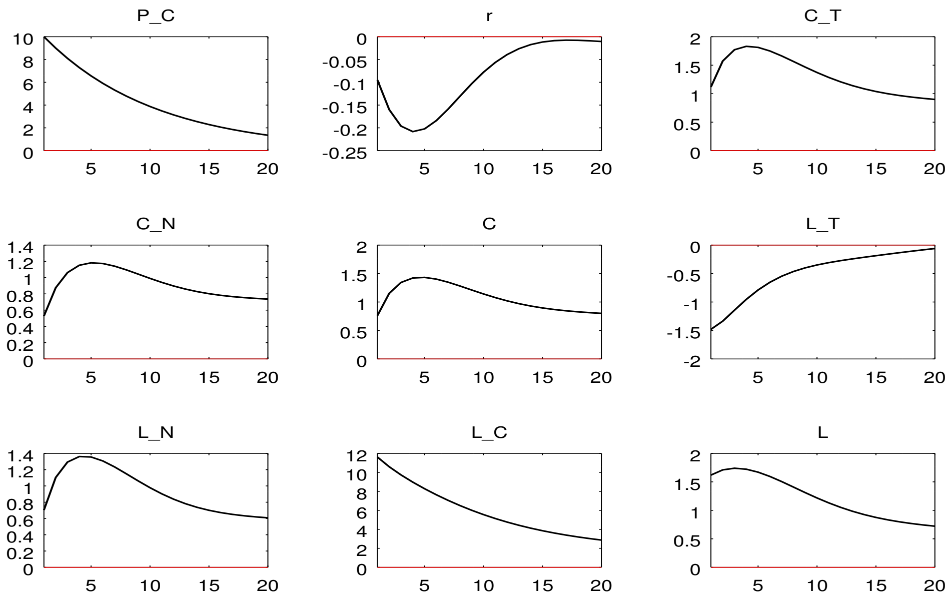
APPENDIX A

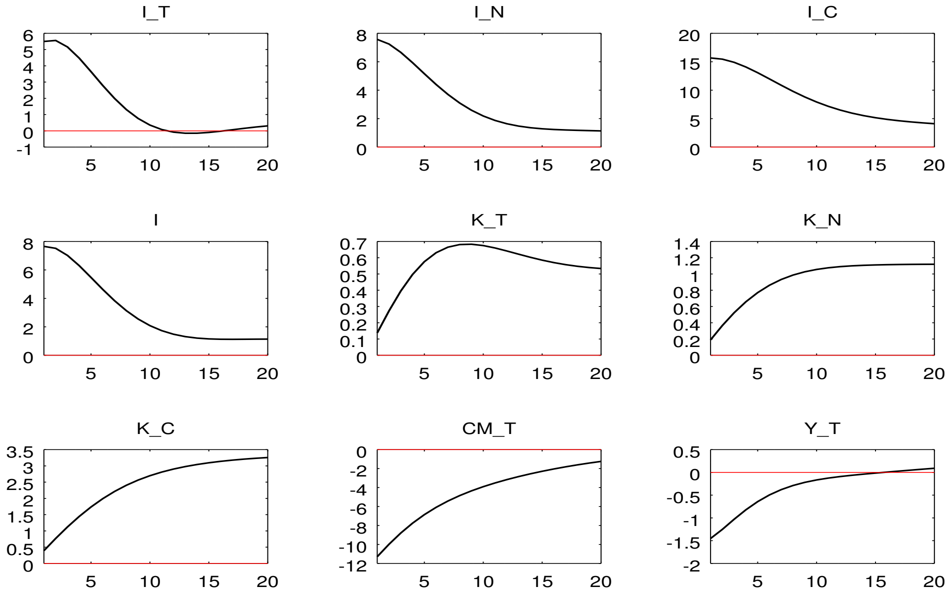
Figures

Figure A.1: Impulse response functions of the baseline model to an unanticipated 10% commodity prices shock.



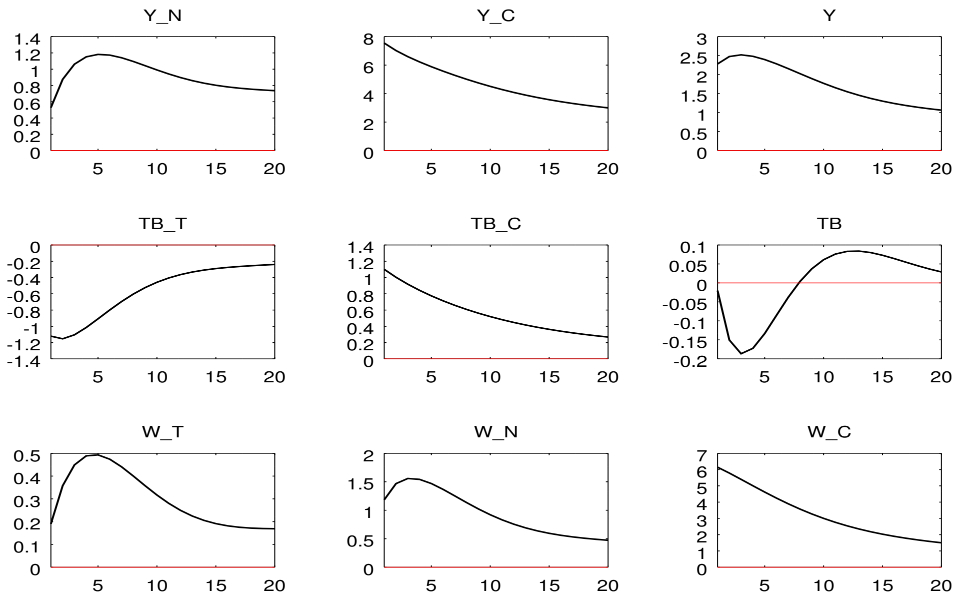
Notes: All variables are expressed in percent deviations from steady state. P_C, r, C_T, C_N, L_T, L_N and L_C denote commodity price, international interest rate, consumption of tradable and nontradable and labor for each sector, respectively.

Figure A.2: Impulse response functions of the baseline model to an unanticipated 10% commodity prices shock.



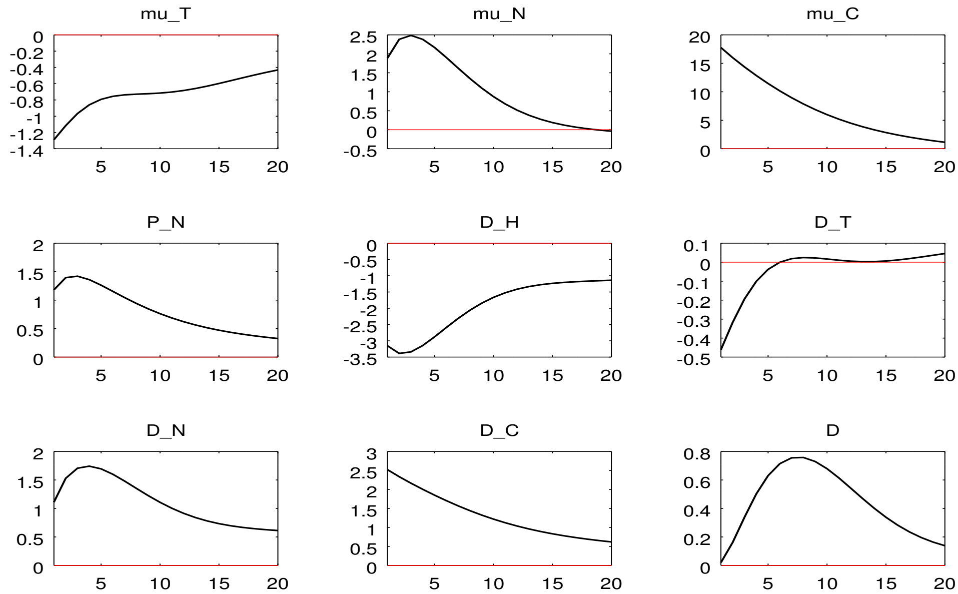
Note: All variables are expressed in percent deviations from steady state. I_T, I_N, I_C, K_T, K_N, K_C, denote investment, capital for each sector and CM_T, Y_T denote demand for commodity goods and production for tradable sector, respectively.

Figure A.3: Impulse response functions of the baseline model to an unanticipated 10% commodity prices shock.



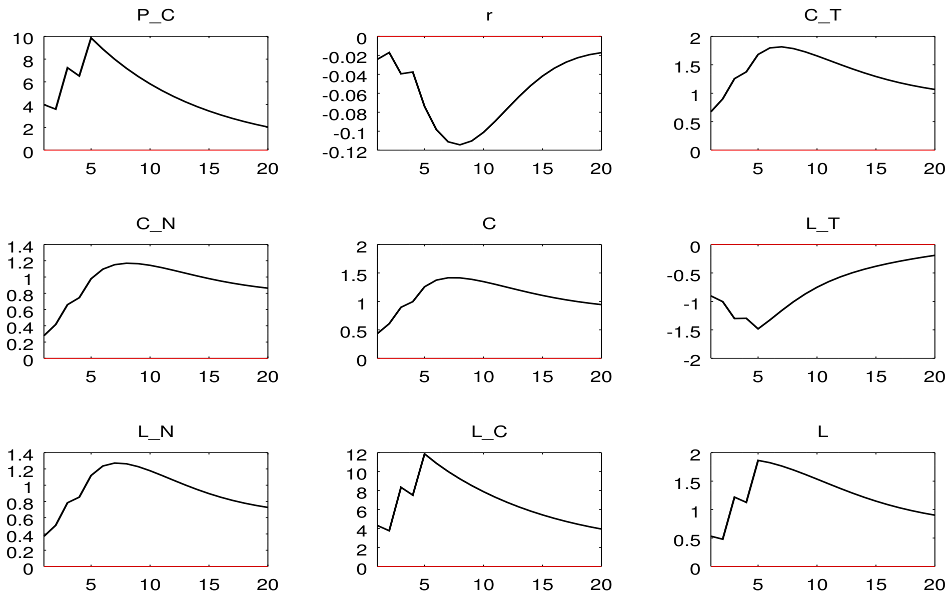
Note: All variables are expressed in percent deviations from steady state. Y_N, Y_C, TB_T, TB_C W_T, W_N, W_C denote production, trade balance and wage rate for nontradable, commodity and tradable sectors, respectively.

Figure A.4: Impulse response functions of the baseline model to an unanticipated 10% commodity prices shock.



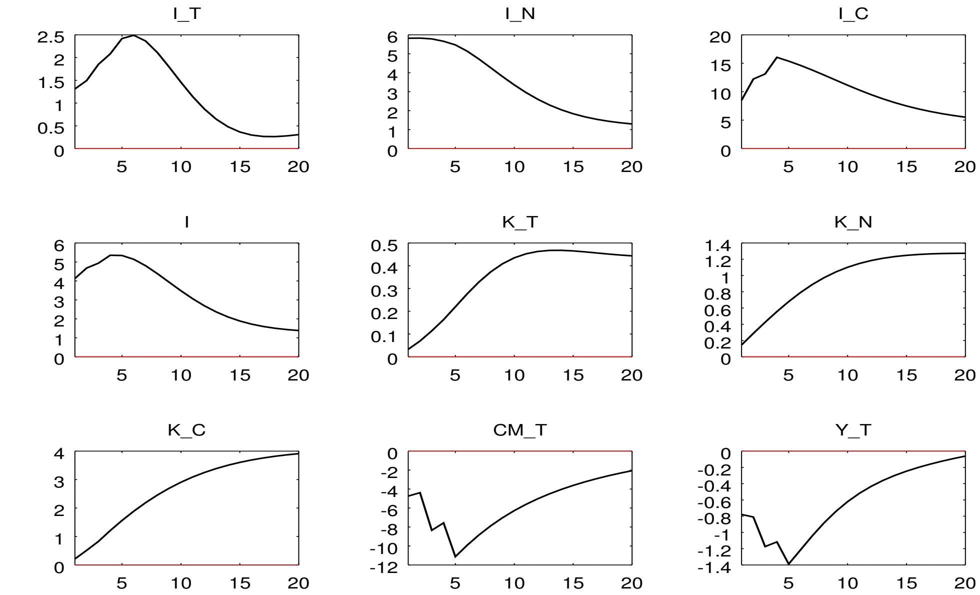
Note: All variables are expressed in percent deviations from steady state. mu_T, mu_N, mu_C, P_N, D_H, D_T, D_N D_C D denote capital rent for each sector, price of nontradable goods, and international borrowing from households and each sector, respectively.

Figure A.5: Impulse response functions of the baseline model to an anticipated 10% commodity prices shock.



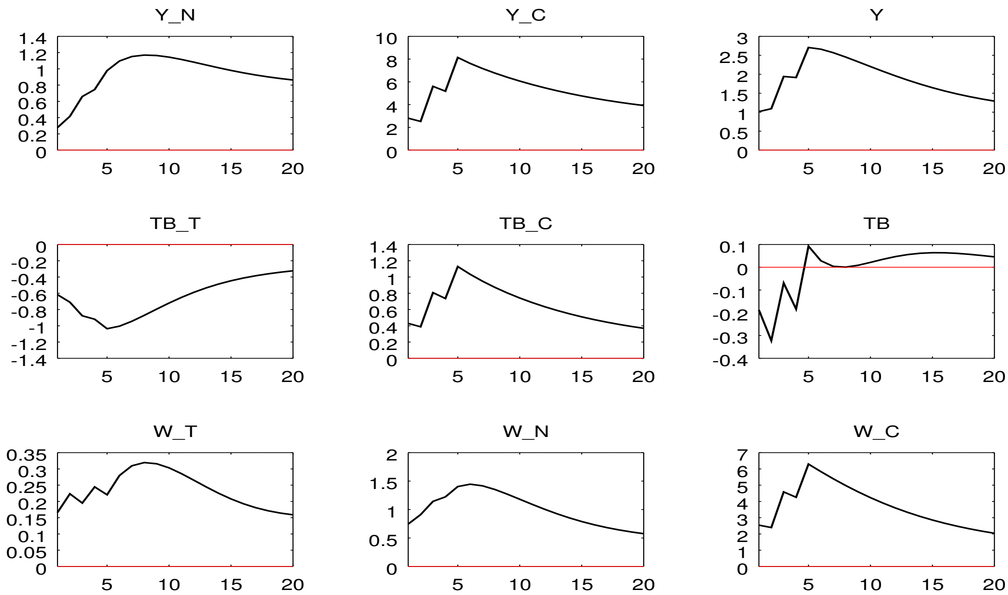
Notes: All variables are expressed in percent deviations from steady state. P_C, r, C_T, C_N, L_T, L_N, L_C denote commodity price, international interest rate, consumption of tradable and nontradable and labor for each sector, respectively.

Figure A.6: Impulse response functions of the baseline model to an anticipated 10% commodity prices shock.



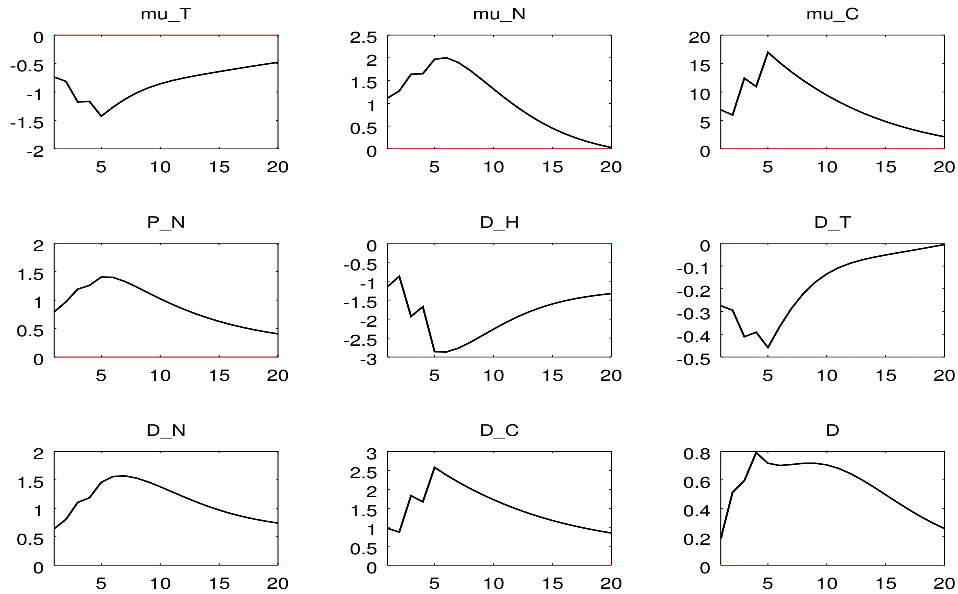
Note: All variables are expressed in percent deviations from steady state. I_T, I_N, I_C, K_T, K_N, K_C, denote investment, capital for each sector and CM_T, Y_T denote demand for commodity goods and production for tradable sector, respectively.

Figure A.7: Impulse response functions of the baseline model to an anticipated 10% commodity prices shock.



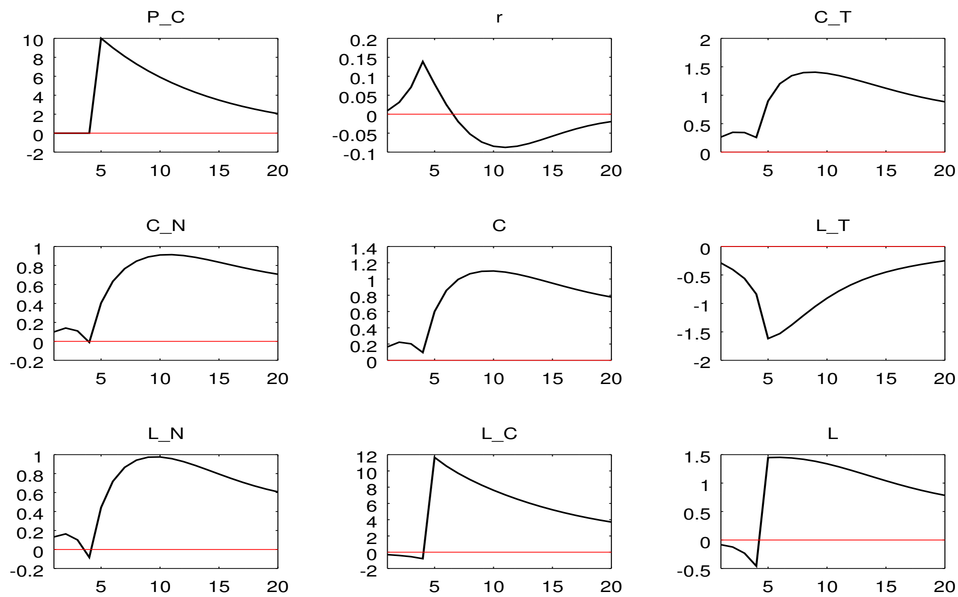
Note: All variables are expressed in percent deviations from steady state. Y_N, Y_C, TB_T, TB_C W_T, W_N, W_C denote production, trade balance and wage rate for nontradable, commodity and tradable sectors, respectively.

Figure A.8: Impulse response functions of the baseline model to an anticipated 10% commodity prices shock.



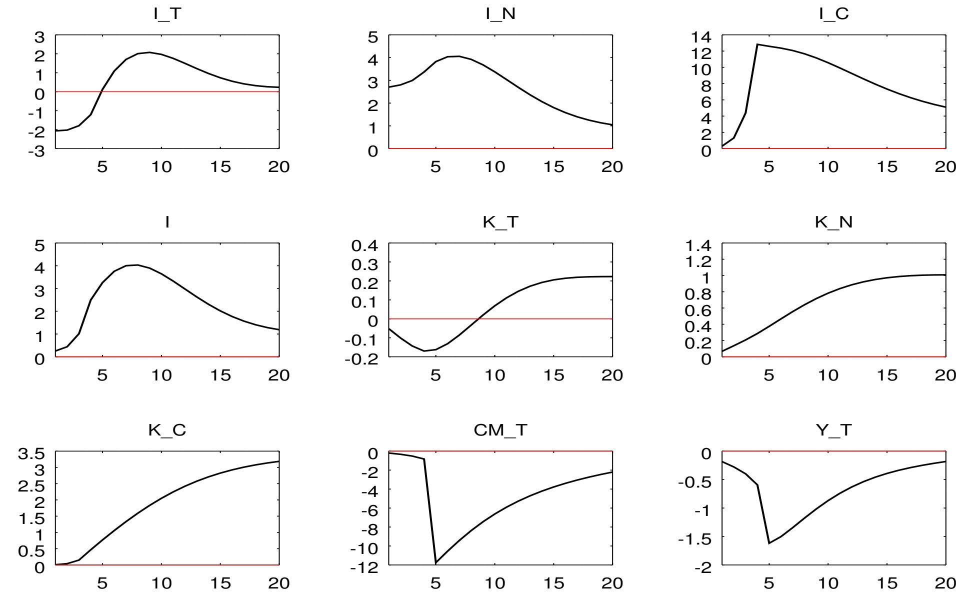
Note: All variables are expressed in percent deviations from steady state. mu_T, mu_N, mu_C, P_N, D_H, D_T, D_N D_C D denote capital rent for each sector, price of nontradable goods, and international borrowing from households and each sector, respectively.

Figure A.9: Impulse response functions of the baseline model to an expected 10% commodity prices shock.



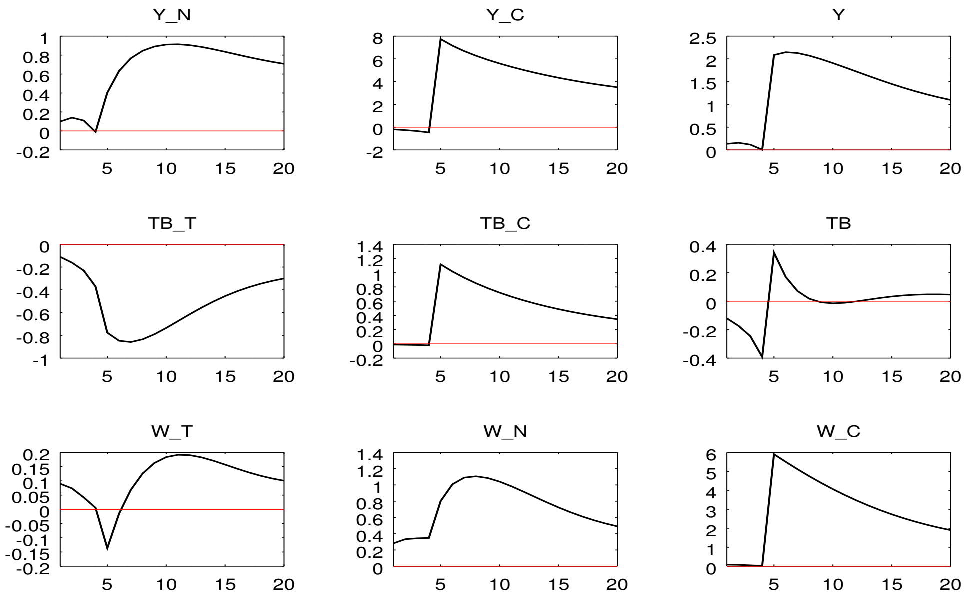
Notes: All variables are expressed in percent deviations from steady state. P_C, r, C_T, C_N, L_T, L_N, L_C denote commodity price, international interest rate, consumption of tradable and nontradable and labor for each sector, respectively.

Figure A.10: Impulse response functions of the baseline model to an expected 10% commodity prices shock.



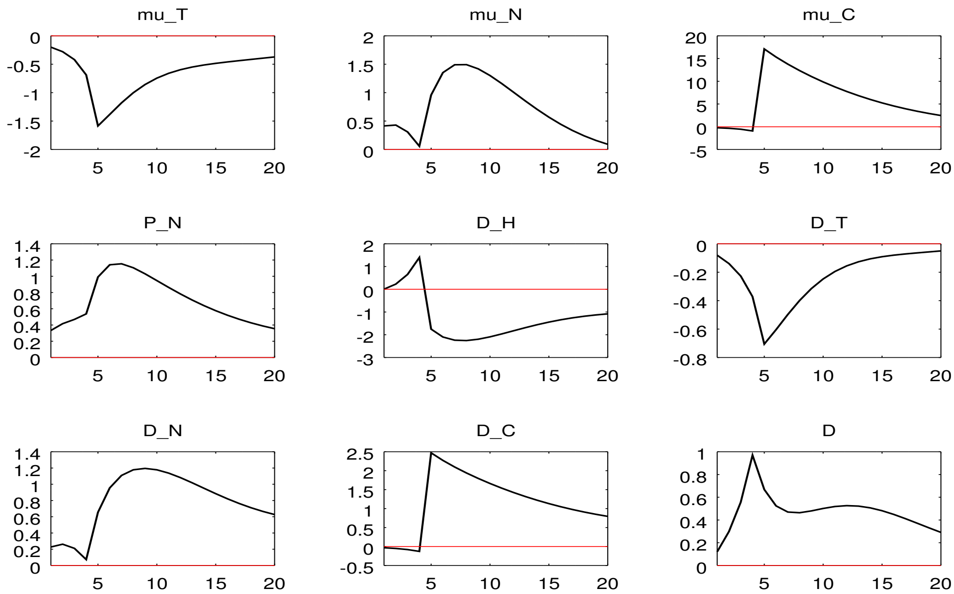
Note: All variables are expressed in percent deviations from steady state. I_T, I_N, I_C, K_T, K_N, K_C, denote investment, capital for each sector and CM_T, Y_T denote demand for commodity goods and production for tradable sector, respectively.

Figure A.11: Impulse response functions of the baseline model to an expected 10% commodity prices shock.



Note: All variables are expressed in percent deviations from steady state. Y_N, Y_C, TB_T, TB_C W_T, W_N, W_C denote production, trade balance and wage rate for nontradable, commodity and tradable sectors, respectively.

Figure A.12: Impulse response functions of the baseline model to an expected 10% commodity prices shock.



Note: All variables are expressed in percent deviations from steady state. mu_T, mu_N, mu_C, P_N, D_H, D_T, D_N D_C D denote capital rent for each sector, price of nontradable goods, and international borrowing from households and each sector, respectively.

APPENDIX B

Equilibrium Conditions

- Consumption basket:

$$c = \left[\chi(c^T)^{(\frac{\varphi-1}{\varphi})} + (1-\chi)(c^N)^{(\frac{\varphi-1}{\varphi})}\right]^{\frac{\varphi}{\varphi-1}}. \tag{B.1}$$

- Lagrange Multiplier:

$$\lambda_t = [U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) + \beta E_t(U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}))]A'_{c_t^T}(c_t^T, c_t^N). \tag{B.2}$$

- Price of Nontradable:

$$p_t^N = \frac{[U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) + \beta E_t(U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}))]A'_{c_t^N}(c_t^T, c_t^N)}{\lambda_t}. \tag{B.3}$$

- Labor supply for each sector:

$$-U'_{l_t^T}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^T, \tag{B.4}$$

$$-U'_{l_t^N}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^N, \tag{B.5}$$

$$-U'_{l_t^{CM}}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \lambda_t w_t^{CM}. \tag{B.6}$$

- Capital optimal condition for each condition:

$$\lambda_t[1+\Phi'_{K^T_{t+1}}(K^T_{t+1},K^T_t)] = \beta E_t\{\lambda_{t+1}[(1-\delta)-\Phi'_{K^T_{t+1}}(K^T_{t+2},K^T_{t+1})+\mu^T_{t+1}]\}, \quad \text{(B.7)}$$

$$\lambda_t[1+\Phi'_{K^N_{t+1}}(K^N_{t+1},K^N_t)] = \beta E_t\{\lambda_{t+1}[(1-\delta)-\Phi'_{K^N_{t+1}}(K^N_{t+2},K^N_{t+1})+\mu^N_{t+1}]\}, \quad \text{(B.8)}$$

$$\lambda_t[1+\Phi'_{K^{CM}_{t+1}}(K^{CM}_{t+1},K^{CM}_t)] = \beta E_t\{\lambda_{t+1}[(1-\delta)-\Phi'_{K^{CM}_{t+1}}(K^{CM}_{t+2},K^{CM}_{t+1})+\mu^{CM}_{t+1}]\}. \quad \text{(B.9)}$$

- Euler equation for households debt position:

$$\lambda_t = \beta(1+r_t)E_t\lambda_{t+1}. \quad \text{(B.10)}$$

- Laws of motion for Capital:

$$K^N_{t+1} = (1-\delta)K^N_t + i^N_t, \quad \text{(B.11)}$$

$$K^C_{t+1} = (1-\delta)K^C_t + i^C_t, \quad \text{(B.12)}$$

$$K^T_{t+1} = (1-\delta)K^T_t + i^T_t. \quad \text{(B.13)}$$

- Optimal demand for capital for each sector:

$$K^N_t = \frac{p^N_t \alpha^N Y^N_t}{\mu^N_t\left[1+\eta^N\left(\frac{r_t}{1+r_t}\right)\right]}, \quad \text{(B.14)}$$

$$K^{CM}_t = \frac{p^{CM}_t \alpha^{CM} Y^{CM}_t}{\mu^{CM}_t\left[1+\eta^{CM}\left(\frac{r_t}{1+r_t}\right)\right]}, \quad \text{(B.15)}$$

$$K^T_t = \frac{\alpha^T Y^T_t}{\mu^T_t\left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right]}. \quad \text{(B.16)}$$

- Optimal demand for labor services for each sector:

$$l^N_t = \frac{p^N_t(1-\alpha^N)Y^N_t}{w^N_t\left[1+\eta^N\left(\frac{r_t}{1+r_t}\right)\right]}, \quad \text{(B.17)}$$

$$l_t^{CM} = \frac{p_t^{CM}(1-\alpha^{CM})Y_t^{CM}}{w_t^{CM}\left[1+\eta^{CM}\left(\frac{r_t}{1+r_t}\right)\right]}, \tag{B.18}$$

$$l_t^{T} = \frac{(1-\alpha^{T}-\gamma^T)Y_t^{T}}{w_t^{T}\left[1+\eta^{T}\left(\frac{r_t}{1+r_t}\right)\right]}. \tag{B.19}$$

- Commodity demand for tradable sector:

$$CM_t^T = \frac{\gamma^T Y_t^T}{p_t^{CM}\left[1+\eta^{T}\left(\frac{r_t}{1+r_t}\right)\right]}. \tag{B.20}$$

- Debt position for each sector:

$$d_t^N = (1+r_{t-1})d_{t-1}^N + \eta^N\left[\frac{w_t^N l_t^N + \mu_t^N K_t^N}{1+r_t} - (w_{t-1}^N l_{t-1}^N + \mu_{t-1}^N K_{t-1}^N)\right], \tag{B.21}$$

$$d_t^{CM} = (1+r_{t-1})d_{t-1}^{CM} + \eta^{CM}\left[\frac{w_t^{CM} l_t^{CM} + \mu_t^{CM} K_t^{CM}}{1+r_t} - (w_{t-1}^{CM} l_{t-1}^{CM} + \mu_{t-1}^{CM} K_{t-1}^{CM})\right], \tag{B.22}$$

$$\begin{aligned} d_t^T = (1++r_{t-1})d_{t-1}^T + \eta^T\Bigg[&\frac{w_t^T l_t^T + \mu_t^T K_t^T + p_t^{CM} CM_t^T}{1+r_t} \\ &- (w_{t-1}^T l_{t-1}^T + \mu_{t-1}^T K_{t-1}^T + p_{t-1}^{CM} CM_{t-1}^T)\Bigg]. \end{aligned} \tag{B.23}$$

- Production function:

$$Y_t^N = A_t^N (K_t^N)^{\alpha^N} (l_t^N)^{1-\alpha^N}, \tag{B.24}$$

$$Y_t^{CM} = A_t^{CM} (K_t^{CM})^{\alpha^{CM}} (l_t^{CM})^{1-\alpha^{CM}}, \tag{B.25}$$

$$Y_t^T = A_t^T (K_t^T)^{\alpha^T} (CM_t^T)^{\gamma^T} (l_t^T)^{1-\alpha^T-\gamma^T}. \tag{B.26}$$

Market Clearing:

- Nontradable sector:

$$c_t^N = Y_t^N, \tag{B.27}$$

- Tradable sector:

$$c_t^T + \sum_{i=\{T,N,CM\}} [i_t^i + \Phi^i(K_{t+1}^i, K_t^i)] + tb_t^T = Y_t^T, \tag{B.28}$$

- Commodity sector:

$$p_t^{CM}(Y_t^{CM} - CM_t^T) = tb_t^{CM}, \tag{B.29}$$

- Total output:

$$Y_t = Y_t^T + p_t^N Y_t^N + tb_t^{CM}, \tag{B.30}$$

- Total Investment:

$$I_t = I_t^T + I_t^N + I_t^{CM}, \tag{B.31}$$

- Total hours worked:

$$L_t = l_t^T + l_t^N + l_t^{CM}, \tag{B.32}$$

- Total trade balance:

$$tb_t^T + tb_t^{CM} = tb_t, \tag{B.33}$$

- Total foreign debt position:

$$d_t = d_t^H + d_t^T + d_t^{CM}, \tag{B.34}$$

- Balance of payments:

$$tb_t - r_{t-1}d_{t-1} = -(d_t - d_{t-1}), \tag{B.35}$$

Exogenous shocks:

$$r_t = (1-\rho^r)\overline{r} + \rho^r r_{t-1} + \mathrm{v}^d(e^{d_t - \overline{d}} - 1) + \mathrm{v}^{CM}(e^{p_t^{CM} - \overline{p}^{CM}} - 1) + e_t^r, \tag{B.36}$$

$$log\left(\frac{p_t^{CM}}{\overline{p}^{CM}}\right) = \rho^{CM} log\left(\frac{p_{t-1}^{CM}}{\overline{p}^{CM}}\right) + \varepsilon_t^{CM} + \varepsilon_{t-2}^{CM} + \varepsilon_{t-4}^{CM}, \tag{B.37}$$

$$log\left(\frac{A_t^N}{\overline{A}^N}\right) = \theta^N log\left(\frac{A_{t-1}^N}{\overline{A}^N}\right) + \epsilon_t^N, \tag{B.38}$$

$$log\left(\frac{A_t^T}{\overline{A}^T}\right) = \theta^T log\left(\frac{A_{t-1}^T}{\overline{A}^T}\right) + \epsilon_t^T, \tag{B.39}$$

$$log\left(\frac{A_t^{CM}}{\overline{A}^{CM}}\right) = \theta^{CM} log\left(\frac{A_{t-1}^{CM}}{\overline{A}^{CM}}\right) + \epsilon_t^{CM}, \tag{B.40}$$

where

$$U'_{c_t}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = \left[c_t - \tau c_{t-1} - \frac{(l_t^T)^{\omega^T}}{\omega^T} - \frac{(l_t^N)^{\omega^N}}{\omega^N} - \frac{(l_t^{CM})^{\omega^C}}{\omega^{CM}}\right]^{-\sigma},$$

$$U'_{c_t}(c_{t+1} - \tau c_t, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}) = (-\tau)\left[c_{t+1} - \tau c_t - \frac{(l_{t+1}^T)^{\omega^T}}{\omega^T} - \frac{(l_{t+1}^N)^{\omega^N}}{\omega^N} - \frac{(l_{t+1}^{CM})^{\omega^C}}{\omega^{CM}}\right]^{-\sigma},$$

$$U'_{l_t^i}(c_t - \tau c_{t-1}, l_t^T, l_t^N, l_t^{CM}) = -(l_t^i)^{(\omega_i - 1)}\left[c_t - \tau c_{t-1} - \frac{(l_t^T)^{\omega^T}}{\omega^T} - \frac{(l_t^N)^{\omega^N}}{\omega^N} - \frac{(l_t^{CM})^{\omega^C}}{\omega^{CM}}\right]^{-\sigma},$$

$$\Phi(K_{t+1}^i, K_t^i) = \frac{\phi^i}{2}(K_{t+1}^i - K_t^i)^2,$$

$$\Phi'_{K_{t+1}^i}(K_{t+1}^i, K_t^i) = \phi_i(K_{t+1}^i - K_t^i),$$

$$\Phi'_{K_{t+1}^i}(K_{t+2}^i, K_{t+1}^i) = -\phi_i(K_{t+2}^i - K_{t+1}^i),$$

for $i = \{T, N, CM\}$, and

$$A'_{c_t^T}(c_t^T, c_t^N) = \chi\left(\frac{c_t}{c_t^T}\right)^{\frac{1}{\varphi}},$$

$$A'_{c_t^N}(c_t^T, c_t^N) = (1-\chi)\left(\frac{c_t}{c_t^N}\right)^{\frac{1}{\varphi}}.$$

APPENDIX C

Steady State Calculation

The steady state level of endogenous variables are the equations described in section B without the subscript t. We set p^{CM}, r and d to their calibrated level. Also, we set $A^T = A^N = A^{CM} = 1$. Then, from equation B.35, we get:

$$tb = rd. \tag{C.1}$$

From equations B.7-B.9, we get:

$$\mu^T = \frac{1}{\beta} - (1 - \delta), \tag{C.2}$$

$$\mu^N = \frac{1}{\beta} - (1 - \delta), \tag{C.3}$$

$$\mu^{CM} = \frac{1}{\beta} - (1 - \delta). \tag{C.4}$$

From equations B.25 and B.15, we get the capital-to-labor ratio for commodity sector:

$$KL^{CM} = \left(\frac{\alpha^{CM} p^{CM} A^{CM}}{\mu^{CM} \left[1 + \eta^{CM} \left(\frac{r}{1+r}\right)\right]} \right)^{\frac{1}{1-\alpha^{CM}}},$$

and from equation B.18, we get wage rate as follows:

$$w^{CM} = \frac{(1 - \alpha^{CM}) p^{CM} A^{CM} (KL^{CM})^{\alpha^{CM}}}{\left[1 + \eta^{CM} \left(\frac{r}{1+r}\right)\right]}.$$

From equations B.16, B.26 and B.20, we the capital-to-labor ratio for tradable sector:

$$KL^T = \left[\frac{\alpha^T \Theta^T A^T}{\mu^T \left[1 + \eta^T \left(\frac{r}{1+r}\right)\right]}\right]^{\frac{1}{1-\alpha^T-\gamma^T}},$$

and also from equation B.19, we get wage rate for this sector:

$$w^T = \frac{(1-\alpha^T-\gamma^T)\Theta^T A^T (KL^T)^{(\alpha^T+\gamma^T)}}{\left[1 + \eta^T \left(\frac{r}{1+r}\right)\right]},$$

where

$$\Theta^T = \frac{\gamma^T \mu^T}{p^{CM} \alpha^T}.$$

Now the following system of equation have to be solve numerically to obtain price of nontradable (p^N), capital-to-labor ration for nontradable goods (KL^N), hours worked in nontradable sector (l^N) and Σ:

$$\mu^N = \frac{\alpha^N p^N A^N (KL^N)^{(\alpha^N-1)}}{\left[1 + \eta^N \left(\frac{r}{1+r}\right)\right]}, \tag{C.5}$$

$$\left[1 + \eta^N \left(\frac{r}{1+r}\right)\right] \left[\frac{\Sigma}{1-\tau\beta}(l^N)^{(\omega^N-1)}\right] = (1-\alpha^N) p^N A^N (KL^N)^{\alpha^N}, \tag{C.6}$$

$$\Sigma = \left[\chi^\varphi + (1-\chi)^\varphi (p^N)^{(1-\varphi)}\right]^{1/(1-\varphi)}, \tag{C.7}$$

$$p^N = \left(\frac{1-\chi}{\chi}\right)\left(\frac{c^T}{c^N}\right)^{\frac{1}{\varphi}}, \tag{C.8}$$

where

$$c^T = Y^T - [I^T + \Phi(K^T_{t+1}, K^T_t) + I^N + \Phi(K^N_{t+1}, K^N_t) + I^{CM} + \Phi(K^{CM}_{t+1}, K^{CM}_t)],$$

$$c^N = Y^N,$$

$$Y^T = \Theta^T A^T (KL^T)^{(\gamma^T+\alpha^T)} l^T,$$

$$Y^N = A^N (KL^N)^{\alpha^N} l^N,$$

$$I^T = \delta(KL^T) l^T,$$

$$I^{CM} = \delta(KL^{CM})l^{CM},$$

$$I^{N} = \delta(KL^{N})l^{N},$$

$$tb^{T} = tb - tb^{CM},$$

$$tb^{CM} = p^{CM}(Y^{CM} - CM^{T}),$$

$$Y^{CM} = A^{CM}(KL^{CM})^{\alpha^{CM}}(l^{CM}),$$

$$CM^{T} = \frac{\gamma^{T}Y^{T}}{p^{CM}\left[1+\eta^{T}\left(\frac{r}{1+r}\right)\right]},$$

$$l^{T} = \left[\frac{(1-\tau\beta)w^{T}}{\Sigma}\right]^{1/(\omega^{T}-1)},$$

$$l^{CM} = \left[\frac{(1-\tau\beta)w^{CM}}{\Sigma}\right]^{1/(\omega^{CM}-1)}.$$

Once we have the values for $p^{CM}, r, d, A^{T}, A^{CM}, A^{N}, tb, KL^{CM},\ w^{CM}, KL^{T}, w^{T}, p^{N}$, KL^{N}, l^{N}, we are able to find the values for the remaining endogenous variables at the steady state.

From labor supply optimal conditions B.4-B.6, we get:

$$l^{CM} = \left[\frac{(1-\tau\beta)w^{CM}}{\Sigma}\right]^{1/(\omega^{CM}-1)}, \tag{C.9}$$

$$l^{T} = \left[\frac{(1-\tau\beta)w^{T}}{\Sigma}\right]^{1/(\omega^{T}-1)}, \tag{C.10}$$

$$w^{N} = \frac{\Sigma(l^{N})^{(\omega^{N}-1)}}{(1-\tau\beta)}. \tag{C.11}$$

From the definition of capital-to-labor ratio, the capital stock in the steady state is found by:

$$K^{T} = (KL^{T})l^{T}, \tag{C.12}$$

$$K^{N} = (KL^{N})l^{N}, \tag{C.13}$$

$$K^{CM} = (KL^{CM})l^{CM}. \tag{C.14}$$

From equations B.15 and B.16, we get the demand for commodity goods from tradable sector:

$$CM^T = \left(\frac{\gamma^T \mu^T}{p^C \alpha^T}\right) K^T. \tag{C.15}$$

From equations B.24-B.26, the production at the steady state for each sector is found by:

$$Y^T = A^T (K^T)^{\alpha^T} (CM^T)^{\gamma^T} (l^T)^{(1-\alpha^T-\gamma^T)}, \tag{C.16}$$

$$Y^N = A^N (K^N)^{\alpha^N} (l^N)^{(1-\alpha^N)}, \tag{C.17}$$

$$Y^{CM} = A^{CM} (K^{CM})^{\alpha^{CM}} (l^{CM})^{(1-\alpha^{CM})}. \tag{C.18}$$

From equation B.29, we get the trade balance for the commodity sector:

$$tb^{CM} = p^{CM} \left(Y^{CM} - CM^T\right). \tag{C.19}$$

From equation B.33, we get the trade balance for tradable sector:

$$tb^T = tb - tb^{CM}. \tag{C.20}$$

From equations B.11-B.13, we get the investment at the steady state:

$$I^T = \delta K^T, \tag{C.21}$$

$$I^N = \delta K^N, \tag{C.22}$$

$$I^{CM} = \delta K^{CM}. \tag{C.23}$$

From equations B.3 and B.27, we get the consumption of tradable and nontradble goods as follows:

$$c^T = \left(\frac{\chi}{1-\chi} p^N\right)^{\varphi} Y^N, \tag{C.24}$$

$$c^N = Y^N. \tag{C.25}$$

From equation B.1, we get the consumption basket as:

$$c = \left[\chi (c^T)^{(\frac{\varphi - 1}{\varphi})} + (1 - \chi)(c^N)^{(\frac{\varphi - 1}{\varphi})} \right]^{\frac{\varphi}{\varphi - 1}}. \tag{C.26}$$

From equations B.21-B.23, we get the steady state debt position for each sector and households by:

$$d^N = \eta^N \left(\frac{w^N l^N + \mu^N K^N}{1 + r} \right), \tag{C.27}$$

$$d^{CM} = \eta^{CM} \left(\frac{w^{CM} l^{CM} + \mu^{CM} K^{CM}}{1 + r} \right), \tag{C.28}$$

$$d^T = \eta^T \left(\frac{w^T l^T + \mu^T K^T + CM^T p^C}{1 + r} \right), \tag{C.29}$$

$$d^H = d - d^T - d^N - d^{CM}. \tag{C.30}$$

From equations B.30-B.32, total output, investment and hours worked are found by:

$$Y = Y^T + p^N Y^N + tb^{CM}, \tag{C.31}$$

$$I = I^T + I^N + I^{CM}, \tag{C.32}$$

$$L = l^T + l^N + l^{CM}. \tag{C.33}$$

From equation B.2, we get the lagrange multiplier as:

$$\lambda = (1 - \tau\beta) \left[\chi \left(\frac{c}{c^T} \right)^{\frac{1}{\varphi}} \right] \left[(1 - \tau)c - \frac{(l^T)^{\omega^T}}{\omega^T} - \frac{(l^N)^{\omega^N}}{\omega^N} - \frac{(l^{CM})^{\omega^{CM}}}{\omega^{CM}} \right]^{-\sigma}. \tag{C.34}$$