Received 13 February 2023
Revised 20 July 2023
Accepted 24 July 2023

Commodity prices and business cycles in small open economies: the role of news shocks

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Abstract

Purpose – The authors explore the hypothesis that some movements in commodity prices are anticipated (news shocks) and can trigger aggregate fluctuations in small open emerging economies. This paper aims to discuss the aforementioned objective.

Design/methodology/approach – The authors build a multi-sector dynamic stochastic general equilibrium model with endogenous commodity production. There are five exogenous processes: a country-specific interest rate shock that responds to commodity price fluctuations, a productivity (TFP) shock for each sector and a commodity price shock. Both TFP and commodity price shocks are composed of unanticipated and anticipated components.

Findings – The authors show that news shocks to commodity prices lead to higher output, investment and consumption, and a countercyclical movement in the trade-balance-to-output ratio. The authors also show that commodity price news shocks explain about 24% of output aggregate fluctuations in the small open economy.

Practical implications – Given the importance of both anticipated and unanticipated commodity price shocks, policymakers should pay attention to developments in commodity markets when designing policies to attenuate the business cycles. Future research should investigate the design of optimal fiscal and monetary policies in SOE subject to news shocks in commodity prices.

Originality/value – This paper contributes to the knowledge of the sources of fluctuations in emerging economies highlighting the importance of a new source: news shocks in commodity prices.

Keywords DSGE, News shocks, Commodity prices, Small open economies

Paper type Research paper

1. Introduction

The early years of the 21st century witnessed a remarkable growth in commodity prices, and many small, open commodity-exporting economies experienced a similar surge. This trend was particularly evident in emerging economies, leading some analysts to link these countries' growth performance to commodity price behavior.

JEL Classification — E32, F41

The authors thank Rafael Vasconcelos, Cássio Besarria, Paulo Vaz and an anonymous referee for useful comments. The authors also thank seminar participants at Central Bank of Brazil, PIMES Macro Workshop, 2017 Latin American and Caribbean Economic Association – Latin American Meeting of the Econometric Society (2017 LACEA- LAMES) and 2017 Brazilian Econometric Society Meeting. Marcelo thanks the National Council for Scientific and Technological Development – CNPq Brazil for financial support. The usual disclaimer applies.

Research funding: This work was supported by the National Council for Scientific and Technological Development – CNPq (Brazil) under the Grant No. 421701/2016-1.

EconomiA
Vol. 24 No. 2, 2023
pp. 264-311
Emerald Publishing Limited
e-ISSN: 2358-2820
p-ISSN: 1517-7580
DOI 10.1108/ECON-02-2023-0023

In emerging economies, commodity prices are a prominent driver of business cycles, as they constitute a substantial proportion of total exports - more than double that of advanced economies. For example, UN COMTRADE data from 1994-2016 reveals that Brazil, Chile, Colombia, Mexico, and South Africa had an average commodity share of around 60% of total exports. Additionally, during the same period, emerging economies had an average commodity share of about 13% of GDP.

The literature outlines various channels through which a commodity price shock may impact a small, open, commodity-exporting economy. One conventional channel is the spillover effect, whereby higher commodity prices boost revenues in the exporting sector, potentially affecting other sectors in the economy. Another channel is the cost channel, which is particularly relevant for commodity-importing economies where commodities are used as inputs (Kilian, 2008; Kilian & Lewis, 2011; Filardo & Lombardi, 2014). A recently explored channel is the impact of commodity prices on the interest rates faced by small, open economies in international financial markets. Several studies (Bastourre, Carrera, Ibarlucia, & Sardi, 2012; Fernández, González, & Rodriguez, 2018; Shousha, 2016) have documented a negative correlation between commodity prices and country risk spreads, indicating that a commodity price shock may be amplified by the accompanying movements in interest rates in opposite directions.

This paper investigates a novel channel through which commodity price shocks can account for business cycles in small open economies. Our unique approach considers a commodity price formulation in which some anticipated movements may trigger aggregate fluctuations in the economy. We hypothesize that once agents recognize signals about future changes in commodity prices, they will adjust their expectations about the economy, leading to adjustments in current optimal decisions. Thus, positive news about commodity prices is expected to increase expectations for the economy and, in turn, result in higher levels of investment and an expansion phase of the economic cycle [1].

An important question is whether it is plausible to assume that there are anticipated movements in commodity prices. Zeev, Pappa, and Vicondoa (2017) argue that the existence of future markets for commodity goods supports the idea that some movements in commodity prices are anticipated. Kilian and Hicks (2013) suggests the growth in commodity prices experienced from mid-2003 until mid-2008 was largely explained by news about global growth. Therefore, once it is reasonable to assume the existence of this anticipation effect, it is important to understand whether this anticipated component in the commodity prices process can play an important role in explaining business cycles in small open economies.

To investigate the role of anticipated and unanticipated commodity price movements, we develop a multi-sector dynamic stochastic general equilibrium - small open economy model (DSGE-SOE) with endogenous commodity production featuring an interest rate process that responds to commodity price levels and a commodity price process with two sources of disturbances (an unexpected component and an anticipated one). 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 eight periods in advance to agents and reflect small shocks in commodity prices. This news shocks formulation is similar to the one used in Schmitt-Grohé and Uribe (2012).

Besides its effect on the interest rate faced by the domestic economy in international financial markets, commodities are either exported or used as input in the production of the manufactured tradable good. As such, our model captures the channels mentioned above, through which commodity price shocks can affect a small open economy.

Our main finding is that news about future changes in commodity prices are non-negligible sources of business cycles in emerging economies, accounting for roughly 24% of aggregate fluctuations in output, 16% in consumption, 24% in investment and 25% of the trade-balance-to-output ratio. Besides the results from our impulse responses analysis show that news shocks in commodity prices lead to higher output, consumption, investment and hours worked following the shock. This shock also leads to a deterioration of the trade-balance-to-output ratio. Therefore offering an explanation for the countercyclical trade balance found in the data.

This paper is related to two strands of the literature. The first is the literature that studies the sources of business cycles in small open economies. For instance, Mendoza (1991, 1995); Neumeyer and Perri (2005), Uribe and Yue (2006), Aguiar and Gopinath (2007), Garcia-Cicco, Pancrazi and Uribe (2010), Shousha (2016), Drechsel and Tenreyro (2018) to cite just a few. We contribute to this literature by providing evidence of a new source of business cycles in these economies. This paper is also related to the literature that has drawn attention to news shocks as a key driver of business cycles (Beaudry & Portier, 2004, 2006, 2007; Barsky & Sims, 2011; Schmitt-Grohé & Uribe, 2012; Kamber, Theodoridis, & Thoenissen, 2017). We contribute to this literature by showing that news shocks in commodity prices (alongside TFP news shocks) can be an important source of aggregate fluctuations in emerging economies, a fundamental that, at the time of this writing, was not explored yet.

The remainder of this paper is as follows. Section 3 presents the small open economy model featuring endogenous commodity production and news shock. Section 4 presents the solution method and the econometric methodology used to estimate the structural parameters. Section 5 discusses the main results using the baseline model and some additional exercises. Finally, section 6 presents some conclusions.

2. Related literature

In this section, we briefly review some related literature. We start with the literature that discusses the sources of business cycles in small open economies and then we turn to the literature on news-driven business cycles.

Mendoza (1991) is the starting point of the literature that investigates the sources of business cycles in small open economies. He argues that productivity shocks (TFP shocks) are the main driver of aggregate fluctuations in these economies. Mendoza (1995) shows the importance of terms of trade (TOT) shocks in driving business cycles using a dynamic stochastic small open economy model. He shows that TOT shocks explain the majority of the aggregate output fluctuation [2]. Kose (2002) argues that world prices shocks, namely shocks to the world interest rate, prices of capital, intermediate, and primary goods play an important role in driving business cycles in small open developing economies, explaining roughly 88% of aggregate output fluctuations. Neumeyer and Perri (2005) show that shocks to the international interest rate faced by domestic economies can be a major source of output fluctuations in small open economies. Similarly, Uribe and Yue (2006) argue that shocks to the country-specific interest rate spreads can explain about 30% of output fluctuations and, hence, as TFP shocks, can be an important source of aggregate fluctuations.

Aguiar and Gopinath (2007) argue that while temporary TFP shocks are behind aggregate fluctuations in small open developed economies, permanent TFP shocks are indeed a major source of output fluctuations in emerging economies. Garcia-Cicco *et al.* (2010) challenged this view by showing that a small-open-economy real business cycle model driven by nonstationary TFP shock does not perform well in explaining business cycles in emerging countries. However, an augmented model that includes shocks to the country premium and financial frictions performs remarkably better and assigns a negligible role to permanent TFP shocks.

Fornero, Kirchner, and Yany (2016) explored the fact that commodity exporters, such as Brazil, Chile and Peru, have experienced significant deterioration in their respective current accounts even with the surge in commodity prices in the past decade. Using an estimated dynamic stochastic general equilibrium (DSGE) model, where agents can not perfectly distinguish between persistent and transitory movements in commodity prices, for Chilean data, they show that if shocks are believed to be high, then a higher expected rate of return of capital triggers a boom in the economy. Moreover, they show that a relative fraction of investment and current account balance in Chile are explained by commodity price fluctuations.

Fernández *et al.* (2018) documented that emerging economies are, on average, commodity exporters and the interest rate faced by those economies in international markets are countercyclical with respect to commodity prices, 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. They find that the common factor can play an important role in explaining fluctuations in those 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 movements in international interest rates in opposite directions. He also shows that the effects are stronger in emerging economies vis-à-vis advanced countries. To assess the channels that are responsible for this contrast, he builds a multi-sector DSGE small open economy model with financial frictions and concludes that the most relevant channels for the transmission of commodity price shocks are the interest rate faced by the economy in international markets and the working capital constraint.

Drechsel and Tenreyro (2018) also investigate the role of commodity price shocks in driving aggregate fluctuations in emerging countries. They build a small open economy DSGE model that features endogenous commodity production and an interest rate process that endogenously responds to commodity price movements. They estimated their model using Argentine data and show that commodity price shocks can account for a sizable fraction of output growth, consumption growth, investment growth and trade balance variance. Differently from Garcia-Cicco *et al.* (2010), they indicate that nonstationary TFP shocks are an important driver of Argentine business cycles. A result in line with Aguiar and Gopinath (2007)'s the cycle is the trend hypothesis. Our model differs from theirs in a few dimensions. First, we have an additional sector in our model: tradable, non-tradable and commodity. This allows for assessing the impacts of commodity price shocks on the real exchange rate. Second, we introduce news shocks to TFP and commodity prices, in line with recent discussions in the literature. A point that we will make more clear below.

As it can be noted from this brief review, most of the existing literature that assesses the sources of business cycles in emerging economies assumes that the totality of aggregate fluctuations is due to unexpected or surprise shocks. We contribute to this literature by providing an indication of a new source of disturbance to account for the business cycle in emerging economies and showing that anticipated shocks in commodity prices (and TFP) might be a non-negligible component in explaining the business cycle in those economies.

This work is also related to the literature on news shocks. Schmitt-Grohé and Uribe (2012) argue that the idea that changes in expectations about the future evolution of economic fundamentals may trigger aggregate fluctuation goes back at least to Pigou (1929). Cochrane (1994) helped to recover this idea by showing the failure of the most common candidates (i.e. shocks to oil prices, technology, money and credit) to account for the bulk of aggregate fluctuations, whereas news shocks could account for fluctuations [3]. Beaudry and Portier (2004) explore a theory of business cycles on which recessions and booms arise due to difficulties encountered by agents in forecasting the future needs of capital, which they called "Pigou cycles". They present a model with three sectors where agents get imperfect signals (news) about future productivity growth and use these signals they get to make investment decisions. They show that forecast errors may be a key source in the understanding business cycle, as in their model a boom and a recession can arise as a result of overly optimistic expectations about future technological growth.

Beaudry and Portier (2006), Jaimovich and Rebelo (2009), Beaudry, Dupaigne, and Portier (2011), Barsky and Sims (2011), among others, also pursue the goal of identifying and assessing the role of news shocks as a major source of business cycles.

Related to our work is Schmitt-Grohé and Uribe (2012). They investigate how important anticipated shocks are as a source of economic fluctuations in the U.S. economy. Employing an 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 productivity shocks, stationary and nonstationary investment-specific shocks, government spending shocks, wage markup shocks, preference shocks, they show that anticipated shocks explain about half of the fluctuations in their model. Also related to our work is Fujiwara, Hirose and Shintani (2011), which uses a DSGE model for the U.S. and Japan, showing that news shocks in TFP play a comparable role to the standard unanticipated TFP shock. In addition, they show that the relative contribution of news in explaining business cycles is more pronounced in the U.S. than in Japan.

Kamber *et al.* (2017) also assess the hypothesis of news-driven business cycles in small open economies. However, they focus on the development economy case and only consider news on TFP. They present a typical small open economy model augmented to include financial frictions at the firm level that can generate positive comovements between output, consumption, investment and hours worked in response to news on TFP. They perform a VAR analysis to identify news shocks in TFP in the data and show the same positive comovements over the business cycles. They also show that news shocks can explain between 6% to 40% of output fluctuations over a 10-quarter horizon in their sample. Our analysis differs from theirs in a few dimensions: first, we focus on the emerging economy case. This is important because business cycles in these economies are known to be more volatile than in their developed economy counterpart. Second, we present a multi-sector model where news arises not only on TFP in the different sectors but also in commodity prices. We also consider a domestic interest rate process that is affected by the behavior of commodity prices, a recent feature shown to be important in the related literature (Fernández *et al.*, 2018; Shousha, 2016) [4].

We contribute to this branch of the literature by presenting a small open economy model that can be used to assess the role of anticipated shocks in the commodity price process, a fundamental that, at the time of this writing, was not explored yet. Moreover, we find that anticipated commodity price shocks can be a non-negligible source of business cycles in the model.

3. Theoretical model

In this section, we present a model to evaluate the effects of unanticipated and anticipated total productivity factor (TFP) and commodity price shocks to account for business cycles in emerging economies.

The production side is composed of three different sectors producing tradable final goods, non-tradable final goods and commodity intermediate goods. Commodities can be used either as input in 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.* (2018) [5]. Also, firms in each sector face a working capital constraint, which induces a direct response to changes in interest rates on the production side of the model.

Furthermore, the model is populated by households that consume tradable and non-tradable final goods, and are the owners of all physical capital in the economy, for which they face a cost to adjust every period. In addition, households can borrow financial capital from international markets and supply labor to firms in each sector that is also owned by them.

We allow the interest rate faced by the domestic economy in the international markets to be affected by commodity price movements. This feature has been documented in Fernández *et al.* (2018) and Shousha (2016) and can represent an amplification mechanism of commodity price shocks through a financial channel. The novelty of our work is that we consider commodity price and TFP processes that have two sources of disturbance: an unanticipated and an anticipated component. The underlying assumption is that forward-looking agents anticipate some movements in these exogenous processes and will react to these signals (news), which will generate an earlier response in the economic variables.

3.1 Households

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

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

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

The representative household has preferences described by a GHH utility function: [6]

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

where

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

and l_t^T, l_t^N, l_t^{CM} are, respectively, hours worked in the tradable sector, non-tradable sector and commodity sector, $\sigma > 0$ is the coefficient of relative risk aversion and ω_T, ω_N, ω_{CM} are the Frisch elasticity of labor supply for each sector.

The household's lifetime utility is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, l_t^T, l_t^N, l_t^{CM}\right), \tag{1}$$

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

Households have access to two types of assets: 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 to smooth consumption. Also, all firms in the economy are assumed to be owned by households, which will receive all the profits. Thus, households have four sources of income: wages, physical capital rents, international borrowing and profits from firms. Every period they allocate their income consuming tradable and non-tradable goods, choosing how much to invest to replace depreciated capital and increase the net capital stock, for which they face adjustment costs, and paying interest rates for their debt holdings.

Thus, their period-by-period budget constraint, in terms of the numeraire tradable good, is given by

$$c_t^T + p_t^N c_t^N + \sum_i \left[I_t^i + \Phi_i\left(K_{t+1}^i, K_t^i\right) \right] + r_{t-1} d_{t-1}^H = \left(d_t^H - d_{t-1}^H\right) + \sum_i \left(w_t^i l_t^i + \mu_t^i K_t^i + \pi_t^i \right), \tag{2}$$

where

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

denotes the physical capital adjustment cost function, respectively, for $i = \{T, N, CM\}$, namely tradable, non-tradable and commodity sectors, p_t^N is the price of non-tradable good, I_t^i is the investment in capital for the 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 law of motion:

$$K_{t+1}^i = (1-\delta)K_t^i + I_t^i. \tag{3}$$

Households choose contingent plans for consumption of tradable goods (c_t^T), non-tradable 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 (1) subject to their budget constraint (2), the laws of motion of capital (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

$$\begin{aligned}\mathcal{L} \;&= \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \Big\{ U\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) - \lambda_t \Big[c_t^T + p_t^N c_t^N + \sum_i \left[K_{t+1}^i - (1-\delta)K_t^i + \Phi\left(K_{t+1}^i, K_t^i\right) \right] \\ &\quad + r_{t-1} d_{t-1}^H - \left(d_t^H - d_{t-1}^H\right) - \sum_i \left(w_t^i l_t^i + \mu^i k_t^i + \pi^i \right) \Big] \Big\},\end{aligned}$$

where λ_t is the Lagrange multiplier associated with the budget constraint. The optimal conditions associated with the households' problem are (2), (3) for $i = \{T, N, CM\}$, all holding with equality, and

$$\left[U'_{c_t}\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) + \beta \mathrm{E}_t\left(U'_{c_t}\left(c_{t+1}, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}\right)\right)\right] A'_{c_t^T}\left(c_t^T, c_t^N\right) = \lambda_t, \tag{4}$$

$$\left[U'_{c_t}\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) + \beta \mathrm{E}_t\left(U'_{c_t}\left(c_{t+1}, l_{t+1}^T, l_{t+1}^N, l_{t+1}^{CM}\right)\right)\right] A'_{c_t^N}\left(c_t^T, c_t^N\right) = \lambda_t p_t^N, \tag{5}$$

$$-U'_{l_t^T}\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) = \lambda_t w_t^T, \tag{6}$$

$$-U'_{l_t^N}\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) = \lambda_t w_t^N, \tag{7}$$

$$-U'_{l_t^{CM}}\left(c_t, l_t^T, l_t^N, l_t^{CM}\right) = \lambda_t w_t^{CM}, \tag{8}$$

$$\begin{aligned}\lambda_t\left[1+\phi_T\left(\frac{K_{t+1}^T}{K_t^T}-1\right)\left(\frac{K_{t+1}^T}{K_t^T}\right)+\frac{\phi_T}{2}\left(\frac{K_{t+1}^T}{K_t^T}-1\right)^2\right]\\ =\beta \mathrm{E}_t\lambda_{t+1}\left[(1-\delta)-\phi_T\left(\frac{K_{t+2}^T}{K_{t+1}^T}-1\right)\left(\frac{K_{t+2}^T}{K_{t+1}^T}\right)^2+\mu_{t+1}^T\right],\end{aligned} \tag{9}$$

$$\begin{aligned}\lambda_t\left[1+\phi_N\left(\frac{K_{t+1}^N}{K_t^N}-1\right)\left(\frac{K_{t+1}^N}{K_t^N}\right)+\frac{\phi_N}{2}\left(\frac{K_{t+1}^N}{K_t^N}-1\right)^2\right]\\ =\beta \mathrm{E}_t\lambda_{t+1}\left[(1-\delta)-\phi_N\left(\frac{K_{t+2}^N}{K_{t+1}^N}-1\right)\left(\frac{K_{t+2}^N}{K_{t+1}^N}\right)^2+\mu_{t+1}^N\right],\end{aligned} \tag{10}$$

$$\begin{aligned}\lambda_t\left[1+\phi_{CM}\left(\frac{K_{t+1}^{CM}}{K_t^{CM}}-1\right)\left(\frac{K_{t+1}^{CM}}{K_t^{CM}}\right)+\frac{\phi_{CM}}{2}\left(\frac{K_{t+1}^{CM}}{K_t^{CM}}-1\right)^2\right]\\ =\beta \mathrm{E}_t\lambda_{t+1}\left[(1-\delta)-\phi_{CM}\left(\frac{K_{t+2}^{CM}}{K_{t+1}^{CM}}-1\right)\left(\frac{K_{t+2}^{CM}}{K_{t+1}^{CM}}\right)^2+\mu_{t+1}^{CM}\right],\end{aligned} \tag{11}$$

$$\lambda_t = \beta(1+r_t)\mathrm{E}_t\lambda_{t+1}, \tag{12}$$

where

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

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

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

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

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

The interpretation of these equations is as follows: equations (4)-(5) denote that in period t households choose how much to consume tradable and non-tradable goods such as to equate the expected discounted marginal utility of consumption in period t to the marginal utility of wealth; equations (6)-(8) states that the households' labor supply for each sector will be set by equating the disutility of labor to the expected marginal utility value of the wage rate in period t; equations (9)-(11) define the optimal amount of investment in capital goods; and finally, equation (12) is an Euler relation associating the intertemporal rate of substitution in consumption to the interest rate on the international financial asset.

3.2 Commodity and non-tradable sector

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

$$\kappa_t^j \geq \eta^j\left[w_t^j l_t^j\right], \tag{13}$$

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

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

$$\pi_t^j = p_t^j Y_t^j + \left(d_t^j - d_{t-1}^j\right) - r_{t-1}d_{t-1}^j - \mu_t^j K_t^j - w_t^j l_t^j - \left(\kappa_t^j - \kappa_{t-1}^j\right) - \frac{\iota^j}{2}\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)^2 l_t^j, \tag{14}$$

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. The last term denotes a labor adjustment cost, where $\iota \geq 0$ is a parameter. This cost denotes the idea that labor is costly to adjust (i.e. finding, hiring and training a worker is costly) (Jaimovich & Rebelo, 2008). Therefore, with the arrival of news about future developments in productivity or commodity prices, firms will adjust their labor demand in advance. 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

$$\pi_t^j = p_t^j Y_t^j + \frac{a_t^j}{1+r_t} - a_{t-1}^j - \left(\frac{r_t}{1+r_t}\right)\kappa_t^j - \mu_t^j K_t^j - w_t^j l_t^j - \frac{\iota^j}{2}\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)^2 l_t^j, \tag{15}$$

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 (13) holding with equality in equation (15) to eliminate κ_t^j, we get:

$$\pi_t^j = p_t^j Y_t^j + \frac{a_t^j}{(1+r_t)} - a_{t-1}^j - \mu_t^j K_t^j - w_t^j l_t^j \left[1 + \eta^j \left(\frac{r_t}{1+r_t}\right)\right] - \frac{\iota^j}{2}\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)^2 l_t^j, \quad (16)$$

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

Assuming that commodity and non-tradable goods producers have a Cobb-Douglas technology and competitive behavior in output and production factor markets, the firm's 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, subject to the (flow) budget constraint, to the production technology, and a non-Ponzi game borrowing constraint. Formally,

$$\text{Max} \quad \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t^j, \quad (17)$$

subject to

$$\pi_t^j = p_t^j Y_t^j + \frac{a_t^j}{(1+r_t)} - a_{t-1}^j - \mu_t^j K_t^j - w_t^j l_t^j \left[1 + \eta^j \left(\frac{r_t}{1+r_t}\right)\right] - \frac{\iota^j}{2}\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)^2 l_t^j, \quad (18)$$

$$Y_t^j \le A_t^j \left(K_t^j\right)^{\alpha^j} \left(l_t^j\right)^{1-\alpha^j}, \quad (19)$$

$$\lim_{m\to\infty} \mathrm{E}_t \frac{a_{t+m+1}^j}{\prod_{s=0}^{m}(1+r_s)} \le 0, \quad (20)$$

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

$$\mu_t^j K_t^j = p_t^j \alpha^j Y_t^j, \quad (21)$$

$$\frac{(1-\alpha)p_t^j Y_t^j}{l_t^j} - w_t^j\left[1 + \eta^j\left(\frac{r_t}{1+r_t}\right)\right] - \frac{\iota^j}{2}\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)^2 - \iota^j\left(\frac{l_t^j}{l_{t-1}^j} - 1\right)\left(\frac{l_t^j}{l_{t-1}^j}\right) + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\iota^j\left(\frac{l_{t+1}^j}{l_t^j} - 1\right)\left(\frac{l_{t+1}^j}{l_t^j}\right)^2 = 0. \quad (22)$$

Regarding the net liabilities, any process a_t^j satisfying equations (18) and (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

$$d_t^j - d_{t-1}^j = r_{t-1} d_{t-1}^j + \eta^j \left[\frac{w_t^j l_t^j}{1 + r_t} - w_{t-1}^j l_{t-1}^j \right]. \tag{23}$$

Thus, the optimal conditions associated with commodity and non-tradable sectors problems' are (21), (22), (23) and (19) holding with equality.

3.3 Tradable sector

As in the commodity and non-tradable sectors, firms in the tradable sector are also subject to a working capital constraint, which states that firms must hold a fraction η^T of their total expending in labor in the form of the non-interest-bearing asset κ^T. The working capital for the tradable sector takes the form:

$$\kappa_t^T \geq \eta^T \left[w_t^T l_t^T \right].$$

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) to maximize their discounted expected stream of profits, that is:

$$\text{Max} \quad \text{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \pi_t^T, \tag{24}$$

subject to

$$\pi_t^T = Y_t^T + \frac{a_t^T}{(1 + r_t)} - a_{t-1}^T - \mu_t^T K_t^T - p_t^{CM} CM_t^T - w_t^T l_t^T \left[1 + \eta^T \left(\frac{r_t}{1 + r_t} \right) \right] - \frac{\iota^T}{2} \left(\frac{l_t^T}{l_{t-1}^T} - 1 \right)^2 l_t^T, \tag{25}$$

$$Y_t^T \leq A_t^T \left(K_t^T \right)^{\alpha^T} \left(CM_t^T \right)^{\gamma^T} \left(l_t^T \right)^{1 - \alpha^T - \gamma^T}, \tag{26}$$

$$\lim_{m \to \infty} \text{E}_t \frac{a_{t+m+1}^T}{\prod_{s=0}^{m} (1 + r_s)} \leq 0, \tag{27}$$

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 hire labor and physical capital services from perfectly competitive markets, hence the optimal conditions are similarly given by equation (26) holding with equality and

$$K_t^T = \frac{\alpha_T Y_t^T}{\mu_t^T}, \tag{28}$$

$$CM_t^T = \frac{\gamma^T Y_t^T}{p_t^{CM}}, \tag{29}$$

$$\frac{(1-\alpha^T-\gamma^T)Y_t^T}{l_t^T} - w_t^T\left[1+\eta^T\left(\frac{r_t}{1+r_t}\right)\right] - \frac{\iota^T}{2}\left(\frac{l_t^T}{l_{t-1}^T}-1\right)^2 - \iota^T\left(\frac{l_t^T}{l_{t-1}^T}-1\right)\left(\frac{l_t^T}{l_{t-1}^T}\right)+ \beta E_t\frac{\lambda_{t+1}}{\lambda_t}\iota^T\left(\frac{l_{t+1}^T}{l_t^T}-1\right)\left(\frac{l_{t+1}^T}{l_t^T}\right)^2 = 0, \tag{30}$$

$$d_t^T - d_{t-1}^T = r_{t-1}d_{t-1}^T + \eta^T\left[\frac{w_t^T l_t^T}{1+r_t} - w_{t-1}^T l_{t-1}^T\right]. \tag{31}$$

3.4 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 and 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 [7]. 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.* (2018), 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:

$$r_t = (1-\rho^r)\bar{r} + \rho^r r_{t-1} + \mathrm{v}^d\left[e^{\left(d_t-\bar{d}\right)}-1\right] + \mathrm{v}^C\left[e^{\left(p_t^{CM}-\bar{p}^{CM}\right)}-1\right] + \zeta_t^r, \tag{32}$$

where ρ^r governs the autoregressive component of the real interest rate, $\bar{r}$ is the steady-state level of the country-specific interest rate, d_t is the total debt position of the economy in the period t and $\bar{d}$ is its steady-state level, $\bar{p}^{CM}$ 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 the interest rate process [8].

3.5 Exogenous processes

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

$$\log\left(p_t^{CM}\right) = \left(1-\rho_1^{CM}-\rho_2^{CM}\right)\log\left(\bar{p}^{CM}\right) + \rho_1^{CM}\log\left(p_{t-1}^{CM}\right) + \rho_2^{CM}\log\left(p_{t-2}^{CM}\right) + \xi_t^{CM}, \tag{33}$$

$$\log\left(A_t^k\right) = (1-\theta^k)\log\left(\overline{A}^k\right) + \theta^k \log\left(A_{t-1}^k\right) + \epsilon_t^k, \tag{34}$$

with

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

$$\epsilon_t^k = \epsilon_t^{0,k} + \sum_j \epsilon_{t-j}^{news,k},$$

where $\overline{A}^k$ represents the steady-state level for productivity factor for $k = \{AT, AN, AC\}$, namely TFP in tradable, non-tradable and commodity sector, $\overline{p}^{CM}$ represents the steady-state level for commodity price, and ε_t^0, $\epsilon_t^{0,k}$ and ε_{t-j}^{news}, $\epsilon_{t-j}^{news,k}$ are assumed to be *i.i.d.* Gaussian disturbances with mean zero and standard deviation σ_0^{CM}, σ_0^k and σ_{-j}^{news}, $\sigma_{-j}^{news,k}$, respectively. The shocks $\varepsilon_t^{0,k}$ and ϵ_t^0 represent the unanticipated component realized in period t in commodity price and TFP, respectively. The shocks ε_{t-j}^{news} and $\epsilon_{t-j}^{news,k}$ represent j-period anticipated movement in commodity price and TFP processes, respectively. That is ε_{t-j}^{news} and $\epsilon_{t-j}^{news,k}$ are innovations in commodity price and in TFP that realize in period t, but agents learn, receive the news, in advance in period $t-j$. Therefore, despite the fact these shocks will only be materialized in period t, both are part of agents' information set in period $t-j$ and hence can trigger an earlier response to these future innovations. As Schmitt-Grohé and Uribe (2012), we explore a formulation with four and eight-quarters anticipated shocks.

Moreover, there is an exogenous shock to the country-specific interest rate, $\zeta_t^r \sim iid(0, \sigma^r)$. Therefore there are nine sources of stochastic disturbances: a country-specific interest rate shock, an anticipated and unanticipated commodity price shock and an anticipated and unanticipated TFP for each sector.

3.6 Market clearing and some definitions

The market-clearing conditions are:

(1) For the non-tradable sector:

$$c_t^N = Y_t^N, \tag{35}$$

(2) For the tradable sector:

$$c_t^T + \sum_i \left[I_t^i + \Phi^i\left(K_{t+1}^i, K_t^i\right)\right] + tb_t^T = Y_t^T, \tag{36}$$

(3) For the commodity sector:

$$p_t^{CM}\left(Y_t^{CM} - CM_t^T\right) = tb_t^{CM}, \tag{37}$$

The aggregate trade balance, debt position, balance of payments and output are as follows:

(4) Aggregate trade balance:

$$tb_t^T + tb_t^{CM} = tb_t, \tag{38}$$

(5) Aggregate debt position:

$$d_t = d_t^H + d_t^T + d_t^N + d_t^{CM}, \tag{39}$$

(6) Balance of payments:

$$d_t - d_{t-1} = r_{t-1}d_{t-1} - tb_t, \tag{40}$$

(7) Finally, aggregate output:

$$Y_t = Y_t^T + p_t^N Y_t^N + tb_t^{CM}. \tag{41}$$

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

3.7 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

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

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

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

solve the firms' problem.

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

4. Solution method and econometric methodology

The theoretical model is composed of a system of 40 nonlinear equations for 40 endogenous variables with 33 structural parameters. The characterization of the steady-state does not allow us to solve it analytically, so we proceed to achieve the solution 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.

In choosing values for the structural parameters, we follow three strategies. First, we draw from the related literature to calibrate preferences and technology parameters. Second, we set some parameters to match steady-state values. Finally, we estimate the persistence parameters from the commodity price process with a second-order auto-regressive (AR) model, the parameter that governs the sensitivity of the real interest rate to changes in commodity prices and the remaining parameters using Bayesian techniques. Table 1 presents a brief description of the calibrated parameters.

We follow Mendoza (1991) and set $\omega_T = \omega_N = \omega_C = 1.455$ and $\sigma = 2$. We set the elasticity of substitution between tradable and non-tradable (φ) to 0.5, according to Akinci (2011). We set the depreciation rate at 2.5%, which is a standard value in the literature. The parameter χ is set to 0.35 implying a non-tradable good production-to-output ratio of around 40%. 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 $\alpha^N = 0.25$. We set the commodity prices persistence parameters to $\rho_1^{CM} = 1.363$ and $\rho_2^{CM} = -0.439$ from the results of an SVAR model estimation [9]. The parameter that governs the role of commodity prices in the interest rate equation is set to $v_C = -0.0186$ from the results of linear regression (Table 2), while $v_D = 0.00436$ is set to a small value in line with Schmitt-Grohé and Uribe (2003).

The steady-state values of commodity price, debt position and the country-specific interest rate, we set to match long-run relations. Specifically, we set $\bar{p}^{CM}$ to get a long-run value for commodity exports-to-output ratio of 10%, the country interest rate ($\bar{r}$) to 1.5% and the steady-state value for debt position ($\bar{d}$) to get a trade-balance-to-output ratio of 1%. Additionally, we calibrate the discount factor (β) accordingly.

We choose to estimate the parameters for the internal habit formation (τ), the parameters of the working capital constraint ($\eta^T, \eta^N, \eta^{CM}$), the parameters of the labor adjustment cost (ι^T, ι^N, ι^{CM}), the parameters of the capital adjustment cost (ϕ^T, ϕ^N, ϕ^{CM}), the parameters that govern the persistence of the shocks ($\rho^C, \rho^r, \theta^{AN}, \theta^{AN}, \theta^{AC}$), and the standard deviations of the exogenous processes (σ^r, σ_0^{CM}, $\sigma_{-4}^{news^{CM}}$, $\sigma_{-8}^{news^{CM}}$, σ_0^{AT}, $\sigma_{-4}^{news^{AT}}$, $\sigma_{-8}^{news^{AT}}$, σ_0^{AN}, $\sigma_{-4}^{news^{AN}}$, $\sigma_{-8}^{news^{AN}}$, σ_0^{AC}, $\sigma_{-4}^{news^{AC}}$, $\sigma_{-8}^{news^{AC}}$). We proceed with our estimation using Bayesian techniques. This procedure consists in finding the joint posterior distribution of the parameters.

The Metropolis-Hastings algorithm is used to generate draws from the posterior kernel.

Parameter	Value	Source/Target value
Frisch elasticity of labor supply	$\omega_T = \omega_N = \omega_{CM} = 1.455$	Mendoza (1991)
Relative Risk aversion	$\sigma = 2$	Mendoza (1991)
Elasticity of substitution	$\varphi = 0.5$	Akinci (2011)
Depreciation rate	$\delta = 0.025$	10% per year
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 non-tradable output = 40%
Interest rate parameter	$v^d = 0.004$	Small value Schmitt-Grohé and Uribe (2003)
Interest rate parameter	$v^C = -0.019$	Estimated OLS coefficient
AR coefficient of Commodity price	$\rho_1^{CM} = 1.363$	Estimated SVAR(2) process
AR coefficient of Commodity price	$\rho_2^{CM} = -0.49$	Estimated SVAR(2) process

Note(s): The parameters were calibrated with values from the related literature concerning emerging economies
Source(s): Prepared by the authors

Table 1. Calibrated parameter values

		Real interest rate	
	(1)	(2)	(3)
Commodity price	−0.01925*	−0.01861*	−0.01855*
	(0.00294)	(0.00491)	(0.00535)
Output		−0.00421	−0.00466
		(0.02601)	(0.03003)
Trade-balance-to-GDP ratio			−0.00129
			(0.04183)
Observations	84	84	84
R-squared	0.33	0.33	0.33

Note(s): The country-specific interest rate for Brazil is measured as the sum of the US real interest rate and J.P. Morgan's EMBI + sovereign spread. US real interest rate is proxied by the three-month US Treasury Bill minus a measure of expected US inflation. We compute the expected US inflation as the average percentage increase in the US GDP deflator over the previous four quarters. US Three-month Treasury Bill and US GDP deflator are sourced from the Federal Reserve Economic Data (FRED) database. All data are seasonally adjusted using X-13 ARIMA-SEATS. Also, variables are in deviation from a log-linear and log-quadratic trend, except for the Trade Balance which is in deviation from a linear and quadratic trend. We also demean each variable separately. Standard errors in parentheses. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$
Source(s): Prepared by the authors

Table 2.
Regression results

We use prior distributions that have been extensively used in previous studies. For instance, for the working capital constraint parameters, we use a Gamma distribution with a mean of 2 and a standard deviation of 1; for the labor adjustment cost parameters we use a Gamma distribution with a mean of 10 and a standard deviation of 5; for the capital adjustment cost parameters we use a Gamma distribution with mean 10 and standard deviation of 5; for the persistence technology and country-specific interest rate processes, we choose a Beta distribution with a prior mean of 0.5 and standard deviation of 0.2.

Lastly, for the standard deviations of the unexpected shock σ_0^i for $i = \{AT, AN, AC, CM\}$ and σ^r, we use the Inverse Gamma distribution with a prior mean of 0.10 and standard deviation of *Inf*. For the standard deviation of the News shocks (σ_0^i, $\sigma_{-4}^{news^i}$, $\sigma_{-8}^{news^i}$), we follow Schmitt-Grohé and Uribe (2012) and assume gamma distributions, instead of the inverse gamma distribution. The reason for this choice is to allow for a positive probability of value zero for the standard deviation of the news shock. In other words, this formulation allows for the possibility that the anticipated shock does not matter at all to account for any variation in the commodity price process and/or TFP in each sector. Moreover, we also assume that the prior distributions of the standard deviations of the two anticipated components are identical and that the variance of the unanticipated component is 75% of the total variance of the shock. More formally,

$$\frac{\left(\sigma_0^i\right)^2}{\left(\sigma_0^i\right)^2 + \left(\sigma_{-4}^{news^i}\right)^2 + \left(\sigma_{-8}^{news^i}\right)^2} = 0.75.$$

Hence, we set the standard deviations of news shocks to have a prior mean equal to 0.0408 and a standard deviation of 0.02.

4.1 Data used in the estimation

The model is estimated using real output, real consumption, trade balance-to-output ratio and a constructed real commodity price index. Our dataset consists of quarterly data for Brazil over the period 1996:Q1-2016:Q4.

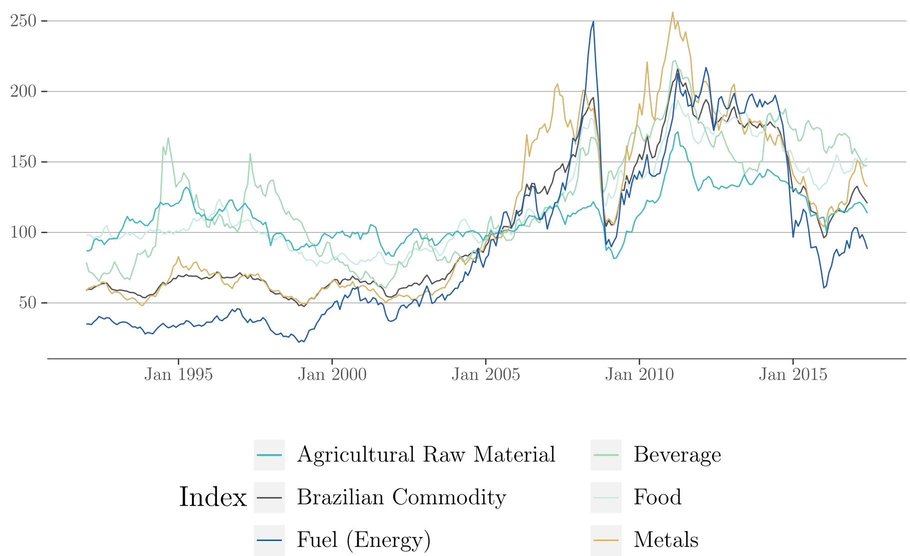
Real output and consumption are measured as Gross Domestic Product (GDP) and households' consumption deflated using GDP deflator for Brazil. The trade balance-to-output ratio is calculated using nominal exports, imports and GDP. The data source is the International Financial Statistics database from International Monetary Fund (IFS-IMF).

For the real commodity price, following Deaton and Miller (1996) and Chen and Rogoff (2003) and similarly to Shousha (2016), we constructed the index as a weighted average of five commodity price indexes using the following methodology: (i) we find the equivalence among commodities codes between Standard International Trade Classification (SITC) revision 04 and the IMF commodities database; (ii) we calculate the value of commodity exports using the United Nations (UN) COMTRADE database for Brazil; (iii) the weights for each commodity are computed by dividing its average value of exports for each primary commodity by the average total value of commodity exports; (iv) we use the previous weights to construct a geometric weighted-average of monthly nominal commodity prices; (v) finally, the commodity price index is deflated using the U.S. import price of manufactured articles from industrialized countries index from the FRED database. The constructed commodity price index can be seen in Figure 1 [10].

All data are seasonally adjusted using X-13 ARIMA-SEATS. Also, variables are in log deviation from a quadratic trend. We also demean each variable separately.

5. Results

In this section, we present our results as follows: first, we describe the estimation of parameters; second, we evaluate the contribution of the news shocks in accounting for business cycles in emerging economies; and finally, we inspect the mechanism behind the resulting dynamic of the model.



Note(s): The Brazilian commodity export price index is constructed as a geometric weighted-average of monthly nominal IMF commodity export prices. Dataset collected from UN Comtrade and IMF Primary Commodity Prices databases
Source(s): Prepared by the authors

Figure 1.
Commodity export price indexes

5.1 Results of the Bayesian estimation of the structural parameters

Tables 3 and 4 summarize the prior distributions, prior means and prior standard deviations used for each estimated parameter and also their respective posterior results.

As stated before, the joint posterior distribution of parameters was obtained using a Metropolis-Hastings algorithm. In particular, we have generated 2 million draws from the posterior distribution. The average acceptance ratio along the chains was around 28%, and

	Prior			Posterior			
	Dist	Param. 1	Param. 2	Mean	Stdev	HPD inf	HPD sup
ρ^r	beta	0.500	0.2000	0.138	0.0773	0.0152	0.2512
ρ^{AT}	beta	0.500	0.2000	0.681	0.1523	0.4615	0.8968
ρ^{AN}	beta	0.500	0.2000	0.763	0.1005	0.6203	0.8977
ρ^{AC}	beta	0.500	0.2000	0.626	0.1694	0.3773	0.8872
ϕ^T	gamm	10.000	5.0000	27.091	6.1498	17.1666	36.8822
ϕ^N	gamm	10.000	5.0000	26.413	6.0715	16.6146	36.1145
ϕ^{CM}	gamm	10.000	5.0000	21.906	5.8056	12.2687	30.8925
η^T	gamm	2.000	1.0000	1.703	0.8075	0.4597	2.8967
η^N	gamm	2.000	1.0000	2.823	1.1384	0.9981	4.6068
η^{CM}	gamm	2.000	1.0000	1.950	0.9855	0.4659	3.3853
ι^T	gamm	10.000	5.0000	3.247	2.2132	0.4258	6.2257
ι^N	gamm	10.000	5.0000	7.709	3.7369	2.0169	13.5069
ι^C	gamm	10.000	5.0000	14.170	5.5727	5.2590	22.5931

Note(s): Posterior statistics are generated using 2 millions draws from the posterior distribution. For uniform prior distributions, "Param. 1" and "Param. 2" refer to the lower and upper bound of the support of the distribution, respectively. For Beta, Gamma and Inverse Gamma distributions, they refer to the mean and standard deviation, respectively

Source(s): Prepared by the authors

Table 3. Results from Metropolis-Hastings (parameters)

	Prior			Posterior			
	Dist	Param.1	Param.2	Mean	Stdev	HPD inf	HPD sup
ζ^r	invg	0.100	Inf	0.018	0.0024	0.0146	0.0223
$\epsilon^{0,AT}$	invg	0.100	Inf	0.019	0.0027	0.0149	0.0235
$\epsilon^{news,AT}_{-4}$	gamm	0.041	0.0100	0.014	0.0030	0.0090	0.0187
$\epsilon^{news,AT}_{-8}$	gamm	0.041	0.0100	0.015	0.0031	0.0096	0.0199
$\epsilon^{0,AN}$	invg	0.100	Inf	0.017	0.0021	0.0139	0.0207
$\epsilon^{news,AN}_{-4}$	gamm	0.041	0.0100	0.011	0.0023	0.0076	0.0151
$\epsilon^{news,AN}_{-8}$	gamm	0.041	0.0100	0.011	0.0023	0.0077	0.0152
$\epsilon^{0,AC}$	invg	0.100	Inf	0.036	0.0089	0.0222	0.0497
$\epsilon^{news,AC}_{-4}$	gamm	0.041	0.0100	0.031	0.0071	0.0196	0.0425
$\epsilon^{news,AN}_{-8}$	gamm	0.041	0.0100	0.032	0.0073	0.0207	0.0445
$\epsilon^{0,CM}$	invg	0.100	Inf	0.051	0.0056	0.0422	0.0603
$\epsilon^{news,CM}_{-4}$	gamm	0.041	0.0100	0.025	0.0051	0.0166	0.0332
$\epsilon^{news,CM}_{-8}$	gamm	0.041	0.0100	0.031	0.0055	0.0220	0.0400

Note(s): Posterior statistics are generated using 2 million draws from the posterior distribution. Invg refers to Inverse gamma distribution. For uniform prior distributions, Param.1 and Param.2 refer to the lower and upper bound of the support of the distribution, respectively. For Beta, Gamma and Inverse Gamma distributions, they refer to the mean and standard deviation, respectively

Source(s): Prepared by the authors

Table 4. Results from Metropolis-Hastings (standard deviation of structural shocks)

we have assessed convergence using the methods proposed by Brooks and Gelman (1998). We have discarded the first 1.6 million draws to assure the independence of initial conditions. The statistics of interest were computed from the ergodic joint posterior distributions of the deep parameters.

Figures 2–4 present the prior and posterior distributions for each parameter. Overall, the results show that the posterior distributions are reasonably different from the prior distributions, indicating that the data are informative about the parameters. Additionally, the estimated values of the parameters are similar to the values obtained in the related literature.

The estimated values for the working capital parameters (η's) in the tradable and non-tradable sector imply that firms maintain a level of working capital equivalent to roughly 5 and 8 months of production wage payments, while in the commodity sector they hold a level of working capital equivalent to 6 months. These values are comparable to the value obtained by Uribe and Yue (2006). The parameters governing the degree of labor adjustment costs faced by firms vary across sectors, ranging from a small value in the tradable sector $\iota^T = 3.347$ to a larger value in the commodity sector $\iota^C = 14.17$. The results also show a small persistence of the interest rate process, while the estimated persistence of the TFP processes is relatively larger.

The posterior estimation of the standard deviations of the exogenous processes (unanticipated and anticipated shocks) exhibits smaller values in comparison to their prior means. However, an interesting result is that the standard deviations of the shocks associated with "news" revealed with 4 (σ_{-4}^{news}) and 8 (σ_{-8}^{news}) periods in advance are significantly larger than zero, which highlights the importance of these shocks in driving the business cycles (Schmitt-Grohé & Uribe, 2012).

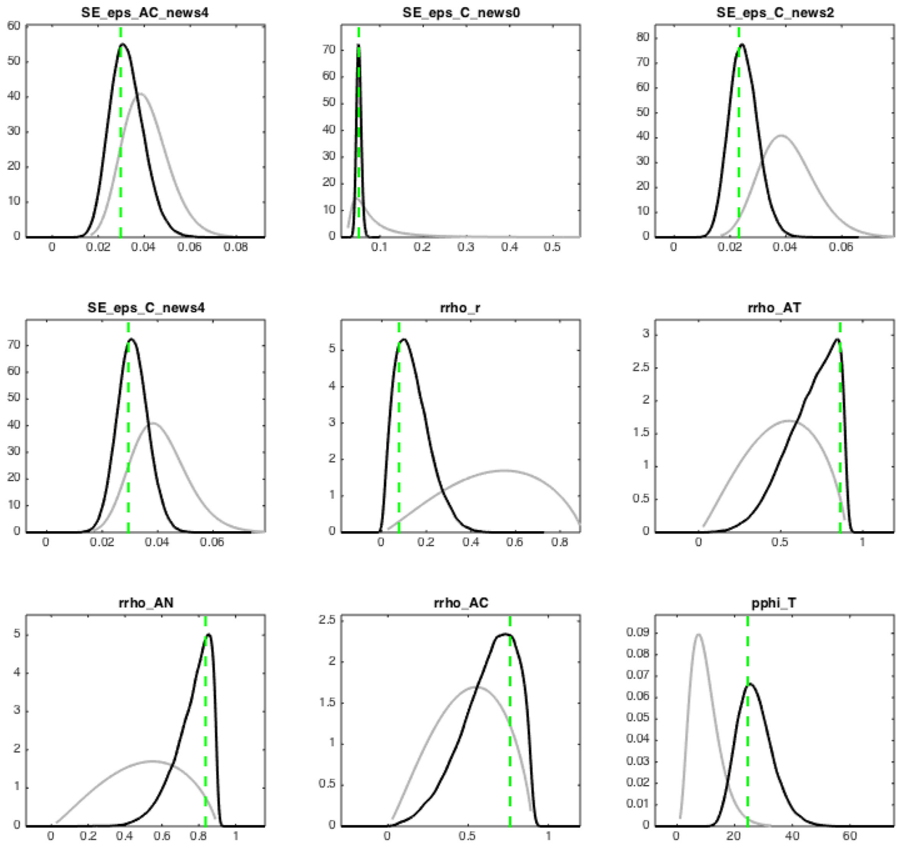
5.2 Model fit

Table 5 shows the model's prediction concerning the standard deviations, auto-correlations, correlations with real output and commodity price of observable time series and their model counterparts. Overall the model replicates (qualitatively) the data moments. The most noticeable difference regards the correlation between the trade-balance-to-output ratio with output and commodity prices. In both cases, the correlation is negative in the data, while the model simulation shows a positive correlation [11].

5.3 The role of news shocks

Now we will investigate how the model behaves in an environment where the exogenous processes for TFP and Commodity prices feature both an unexpected and an anticipated component. The anticipated component is characterized as the sum of two signals received four and eight quarters in advance by agents about an innovation that will occur in a period later.

The novel element is that, differently from early papers on commodity price shocks, the agents' information set is assumed to be larger, as they can observe current and future realizations of the innovations (Schmitt-Grohé & Uribe, 2012). The mechanism works as follows: in each period t, agents observe current and past realizations of the ε_t^0, ε_t^{-4} and ε_t^{-8}, where the last two are realizations of shocks that were anticipated four and eight periods in advance (in periods $t-4$ and $t-8$), respectively. Besides they receive early information (four and eight quarters in advance) about future realizations of innovations to commodity prices and TFP. Hence, agents can predict future innovations in ε_t as follows:



Note(s): Priors and posteriors plot generated by the Bayesian estimation. The x-axis displays part of the support of the prior distribution, while the y-axis displays the corresponding density. The grey line shows the prior density, while the black line shows the density of the posterior distribution
Source(s): Prepared by the authors

Figure 2.
Priors and posteriors

$$\mathbb{E}_t\varepsilon_{t+m} = \begin{cases} \varepsilon^{-4}_{t+m-8} + \varepsilon^{-8}_{t+m-8}, & \text{if } 1 \leq m \leq 4, \\ \varepsilon^{-8}_{t+m-8}, & \text{if } 4 < m \leq 8, \\ 0, & \text{if } m > 8. \end{cases}$$

where m is the forecast horizon.

5.3.1 The importance of news shocks. To evaluate the importance of the anticipated component in exogenous processes to account for business cycles, we implement a forecast error variance decomposition (FEVD) exercise of the main aggregate variables, namely real output, consumption, investment, hours worked and trade balance-to-output ratio. To this end, we arrange the shocks into five distinct subgroups: an unanticipated commodity price

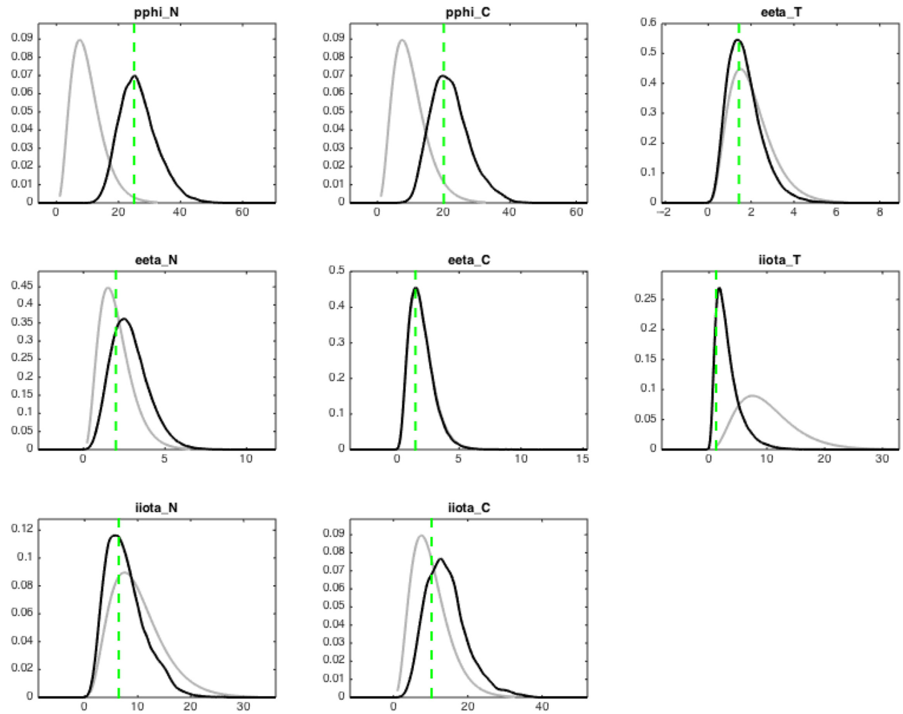
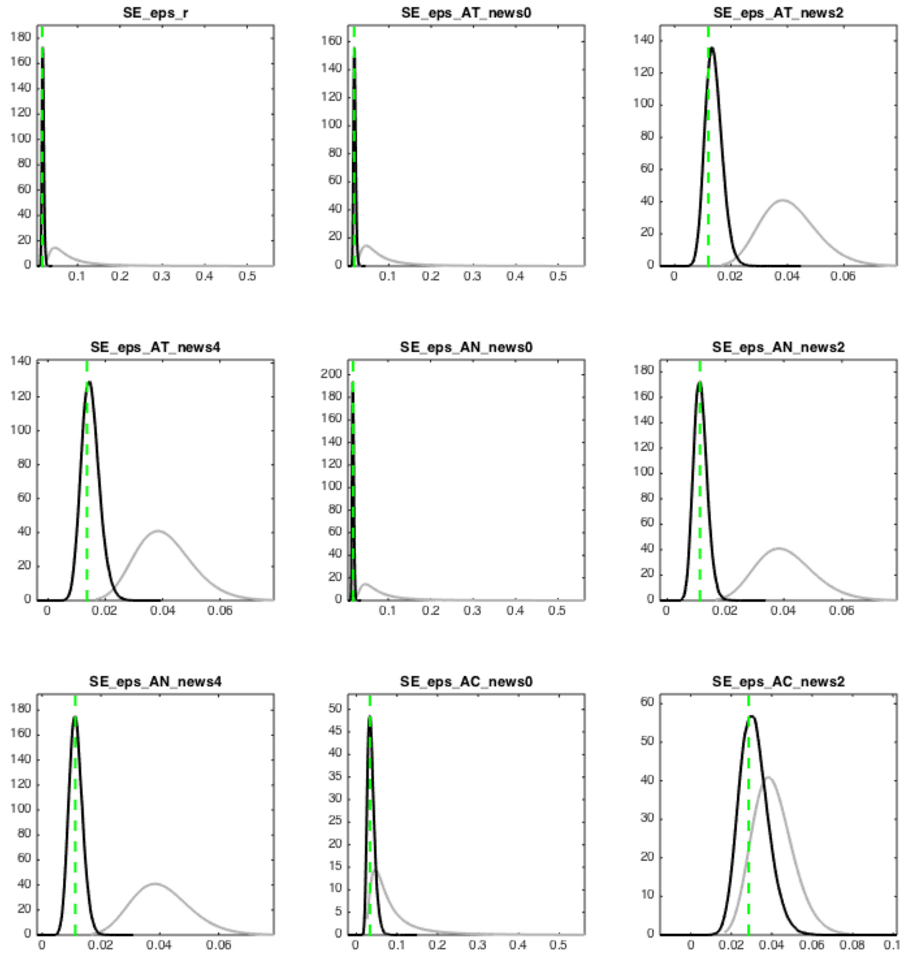


Figure 3.
Priors and posteriors

Note(s): Priors and posteriors plot generated by the Bayesian estimation. The x-axis displays part of the support of the prior distribution, while the y-axis displays the corresponding density. The grey line shows the prior density, while the black line shows the density of the posterior distribution
Source(s): Prepared by the authors

shock (PCOM), news shocks in commodity price (News in PCOM), unanticipated TFP shocks (we add the three TFP shocks: $\epsilon_t^{AT}, \epsilon_t^{AN}, \epsilon_t^{AC}$), news in TFP (we add the contribution of six news shocks: $\epsilon_{t-4}^{news^j}$, $\epsilon_{t-8}^{news^j}$ for $j = AT, AC, AN$) and, then, decompose the variance of the main variables explained by each subgroup. Table 6 presents the relative contribution of the unanticipated and anticipated components in the commodity price process and TFP, as well as the contribution of the country-specific interest rate shocks in explaining aggregate fluctuations in our model.

Some results of the FEVD exercise are important to mention. First, a sizable share of the variance of output, consumption, hours and the trade-balance-to-output ratio can be accounted for by unexpected TFP shocks. However, the importance of TFP shocks declines at longer horizons. The relative importance of unexpected TFP shocks is in line with previous literature (Mendoza, 1991; Garcia-Cicco *et al.*, 2010). Second, unanticipated commodity price shocks also play an important role in driving aggregate fluctuations in our model economy. For output, for example, this shock importance of unanticipated ranges from 35% (two quarters) to almost 49% (eight quarters). This is in line with recent papers that emphasize the importance of commodity price shocks (Drechsel & Tenreyro, 2018; Shousha, 2016). Third, interest rate shocks explain a smaller share of the variance of all main aggregate variables



Note(s): Priors and posteriors plot generated by the Bayesian estimation. The x-axis displays part of the support of the prior distribution, while the y-axis displays the corresponding density. The grey line shows the prior density, while the black line shows the density of the posterior distribution
Source(s): Prepared by the authors

Figure 4.
Priors and posteriors

except for the trade balance-to-output ratio. Drechsel and Tenreyro (2018) also find a similar result for interest rate shocks in their model. Fourth, our results show that the anticipated (news) shocks to TFP can account for a sizable fraction of the variance of the main aggregate variables at a business cycles frequency. Together the anticipated TFP shocks explain about 18% of the variation in real output, 23% in consumption, 10% in investment and roughly 19% in hours worked. Moreover, anticipated components explain around 35% of the variation in the trade balance-to-output ratio. The importance of TFP news shocks in driving aggregate fluctuations is related to previous results in the literature such as Beaudry and Portier (2006), Beaudry *et al.* (2011), Fujiwara *et al.* (2011), Schmitt-Grohé and Uribe (2012), in

	Data σ^X	Model σ^X	Data $\sigma^X/\sigma Y$	Model $\sigma^X/\sigma Y$	Data $\rho(X_t)$	Model $\rho(X_t)$
$\widehat{Y}_t$	0.041	0.099	1	1	0.824	0.968
$\widehat{C}_t$	0.038	0.078	0.924	0.779	0.797	0.982
$\widehat{I}_t$	0.106	0.128	2.59	1.288	0.875	0.943
$\widehat{tby}_t$	0.017	0.024	0.404	0.238	0.896	0.777
$\widehat{r}_t$	0.006	0.02	0.157	0.196	0.818	0.429
$\widehat{P^{CM}}_t$	0.202	0.226	4.932	2.276	0.918	0.973
	$\rho(X_t, Y_t)$	$\rho(X_t, Y_t)$	$\rho(X_t, p_t^{CM})$	$\rho(X_t, p_t^{CM})$		
$\widehat{Y}_t$	1	1	0.818	0.646		
$\widehat{C}_t$	0.842	0.837	0.558	0.455		
$\widehat{I}_t$	0.923	0.895	0.739	0.666		
$\widehat{tby}_t$	−0.436	0.096	−0.157	0.103		
$\widehat{r}_t$	−0.503	−0.303	−0.608	−0.215		

Note(s): The data are the indicators for the Brazilian economy. The data are quarterly from 1996.Q1-2016.Q4. Y, C, I, TBy, p^{CM} and r denote real output, real consumption, real investment, trade balance-to-output ratio, real commodity price and real country-specific interest rate. All data are seasonally adjusted using X-13 ARIMA-SEATS and the trend was removed using a quadratic trend. Column symbols σ, ρ denote standard deviation and correlation, respectively
Source(s): Prepared by the authors

Table 5.
Business cycles statistics

the closed economy context, and Kamber *et al.* (2017) in the open economy context. However, these studies focus on the developed economy case.

Finally, the novelty in our analysis is to show the importance of commodity price news shocks as a new driver of aggregate fluctuations in emerging economies. At the 32-quarter horizon, for instance, these shocks can account for roughly 24% of output fluctuation, 16% of consumption, 24% of investment, 25% of hours worked and 25% of the trade balance-to-output ratio variance. These results are interesting because they highlight the importance of news shocks to commodity prices. When we consider the unanticipated and anticipated commodity price shocks altogether they are responsible for about 64% of output fluctuations. Therefore reinforcing the importance of commodity price shocks as a major driver of aggregate fluctuations in emerging economies. Early literature on the effects of commodity price shocks assumes that the source of fluctuations in this fundamental comes from the standard unanticipated component. In this paper, our results suggest that an important fraction of the fluctuation in commodity prices comes from an anticipated component.

5.3.2 Inspecting the mechanism. Now we assess the effects of news about commodity prices shocks on the business cycles in the model economy. We do this by inspecting the impulse-response functions (IRFs).

Figures 5 and 6 depict the IRFs of output, consumption, investment, hours worked, trade balance-to-output ratio and debt position to one-standard-deviation news shock revealed with 4 and 8 periods in advance about a commodity price movement, respectively. The release of the news will result in an initial positive effect on output, consumption, and investment before the change in commodity prices materializes. Hours worked also increase after the arrival of news. This is the case, as firms face a labor adjustment cost. In the absence of such cost, hours worked fall at impact due to a wealth effect. The country's debt position expands and this leads to an increase in the country-specific interest rate. Eventually, as the news about higher commodity prices materializes, the domestic interest rate will fall. Meanwhile, the trade balance-to-output ratio deteriorates at impact. This last result is interesting because,

Variable	PCOM	News in PCOM	Innovation TFP	News in TFP	Interest rate
Horizon = 2 quarters					
$\widehat{Y}_t$	35.78	1.33	46.55	0.72	15.61
$\widehat{C}_t$	15.28	1.69	51.27	1.02	30.74
$\widehat{I}_t$	46.45	10.05	7.16	3.31	33.03
$\widehat{L}_t$	13.93	0.25	44.51	0.32	40.98
$\widehat{TBY}_t$	7.11	14.9	31.9	5.87	40.22
Horizon = 4 quarters					
$\widehat{Y}_t$	48.78	1.92	37.64	2.09	9.57
$\widehat{C}_t$	24.5	2.87	49.79	2.29	20.55
$\widehat{I}_t$	51.72	13.85	8.47	4.49	21.49
$\widehat{L}_t$	29.15	1.33	42.99	2.37	24.16
$\widehat{TBY}_t$	5.83	23.87	28.83	8.88	32.57
Horizon = 6 quarters					
$\widehat{Y}_t$	48.79	5.27	28.65	10.89	6.4
$\widehat{C}_t$	27.82	4.33	41.65	12.06	14.14
$\widehat{I}_t$	51.56	17.19	9.09	5.35	16.81
$\widehat{L}_t$	35.93	3.85	34.4	10.6	15.22
$\widehat{TBY}_t$	4.7	23.2	23.02	23.38	25.69
Horizon = 8 quarters					
$\widehat{Y}_t$	48.93	8.76	24.57	12.64	5.11
$\widehat{C}_t$	30.1	6.27	37.16	15.23	11.23
$\widehat{I}_t$	50.1	19.94	9.47	6.16	14.33
$\widehat{L}_t$	38.78	7.27	28.84	13.97	11.13
$\widehat{TBY}_t$	4.32	26	21.38	24.79	23.51
Horizon = 16 quarters					
$\widehat{Y}_t$	40.37	21.64	16.5	18.42	3.06
$\widehat{C}_t$	29.73	12.97	26.78	23.81	6.72
$\widehat{I}_t$	46.08	24.18	10.46	8.31	10.98
$\widehat{L}_t$	35.29	20.36	18.29	20.23	5.82
$\widehat{TBY}_t$	3.36	25.22	17.81	35.88	17.73
Horizon = 32 quarters					
$\widehat{Y}_t$	39.33	24.53	15.47	17.98	2.69
$\widehat{C}_t$	31.11	15.97	24.29	23.17	5.46
$\widehat{I}_t$	44.83	23.72	11.5	10.06	9.9
$\widehat{L}_t$	34.82	24.71	16.45	19.27	4.75
$\widehat{TBY}_t$	3.63	25.5	18.58	35.31	16.97

Note(s): PCOM and TFP stand for Commodity price and Total Productivity factor, respectively. The relative contribution of each group of shocks is expressed as percentage points of the corresponding conditional variance decomposition implied by the model. TFP is the sum of the three productivity shocks in each sector
Source(s): Prepared by the authors

Table 6. Forecast error variance decomposition for the stochastic process

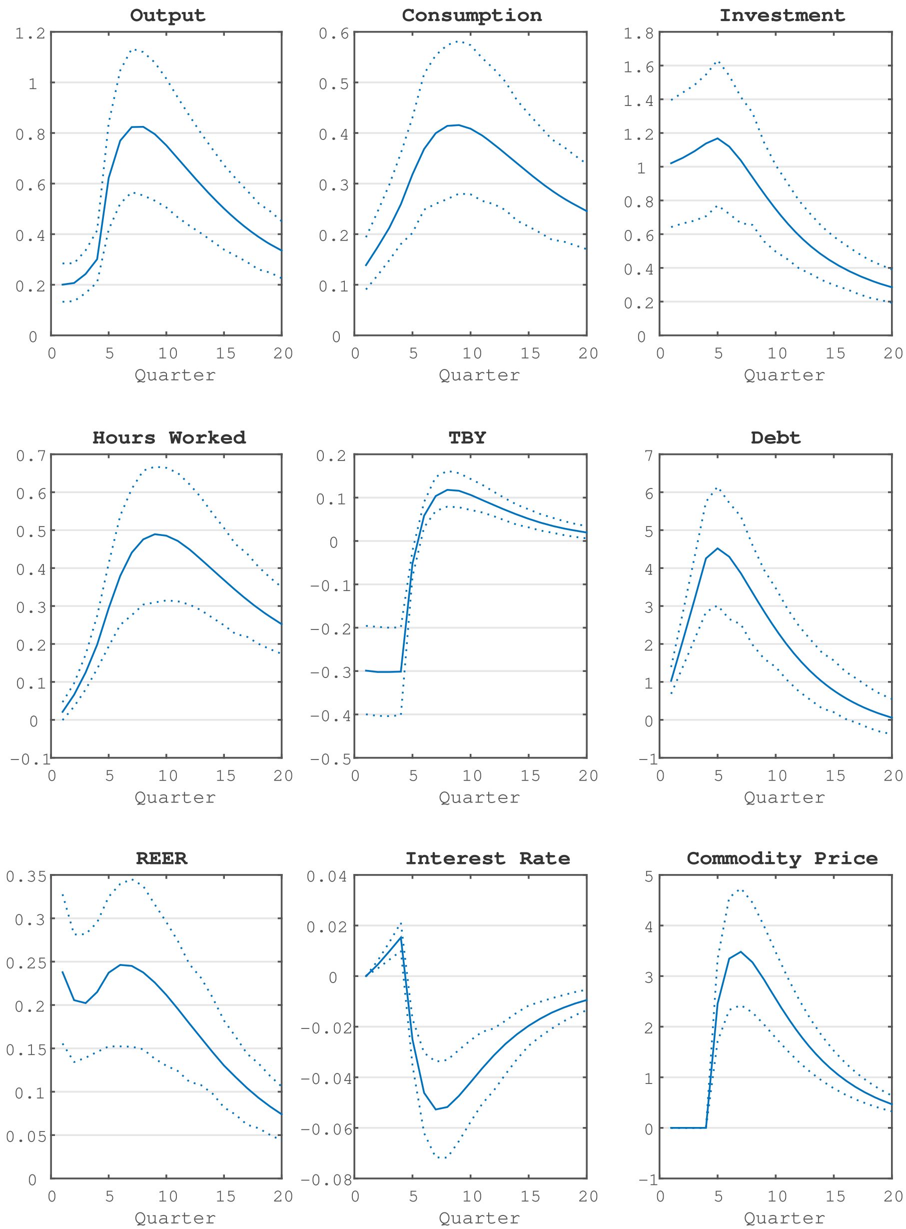
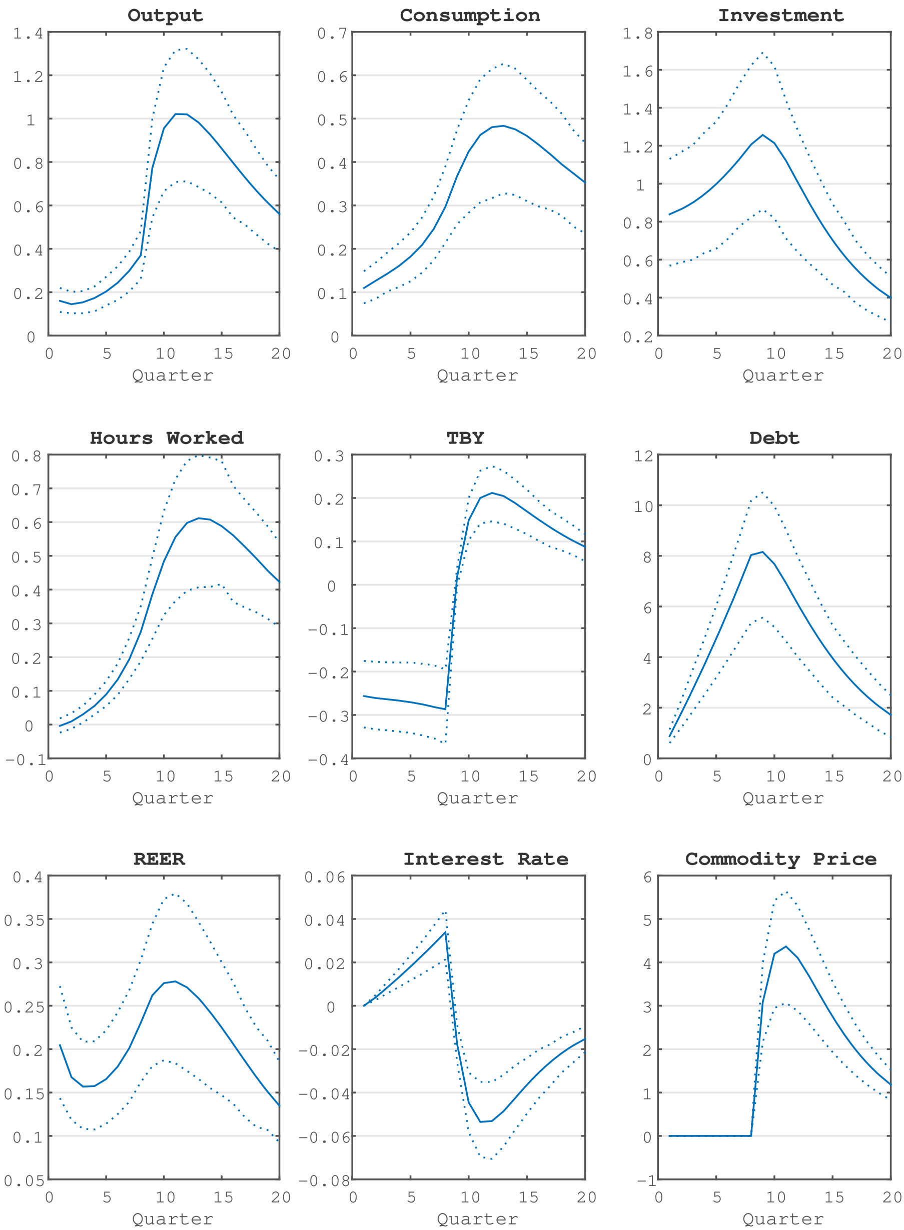


Figure 5.
News shocks in commodity prices $t-4$

Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval

Source(s): Prepared by the authors



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval

Source(s): Prepared by the authors

Figure 6.
News shocks in commodity prices $t-8$

in the data, this variable exhibits a negative correlation with output, which corroborates the importance of news shock to commodity prices as a source of aggregate fluctuations in emerging economies.

The mechanism at play behind this initial dynamic can be explained as follows: the release of news generates an incentive for households to increase investment in anticipation of higher commodity prices in the future. This is the case because households face investment adjustment costs, so it is optimal to distribute the increase in investment over time. This change in investment raises the capital stock and, therefore, the rental rate of capital. This in turn increases households' income and hence represents a positive wealth effect leading to an expansion in consumption.

In the production sector, there is a slight improvement in production as a result of an increase in available physical capital (due to higher investment). This small improvement raises the demand for labor services, leading to a rise in the wage rate. Higher labor and capital disbursements raise the production cost and as a result (due to the working capital constraint), the foreign debt position for the production sector will also increase. Furthermore, these facts will spawn a further favorable increment in households' income, as a result of higher wages and capital rents.

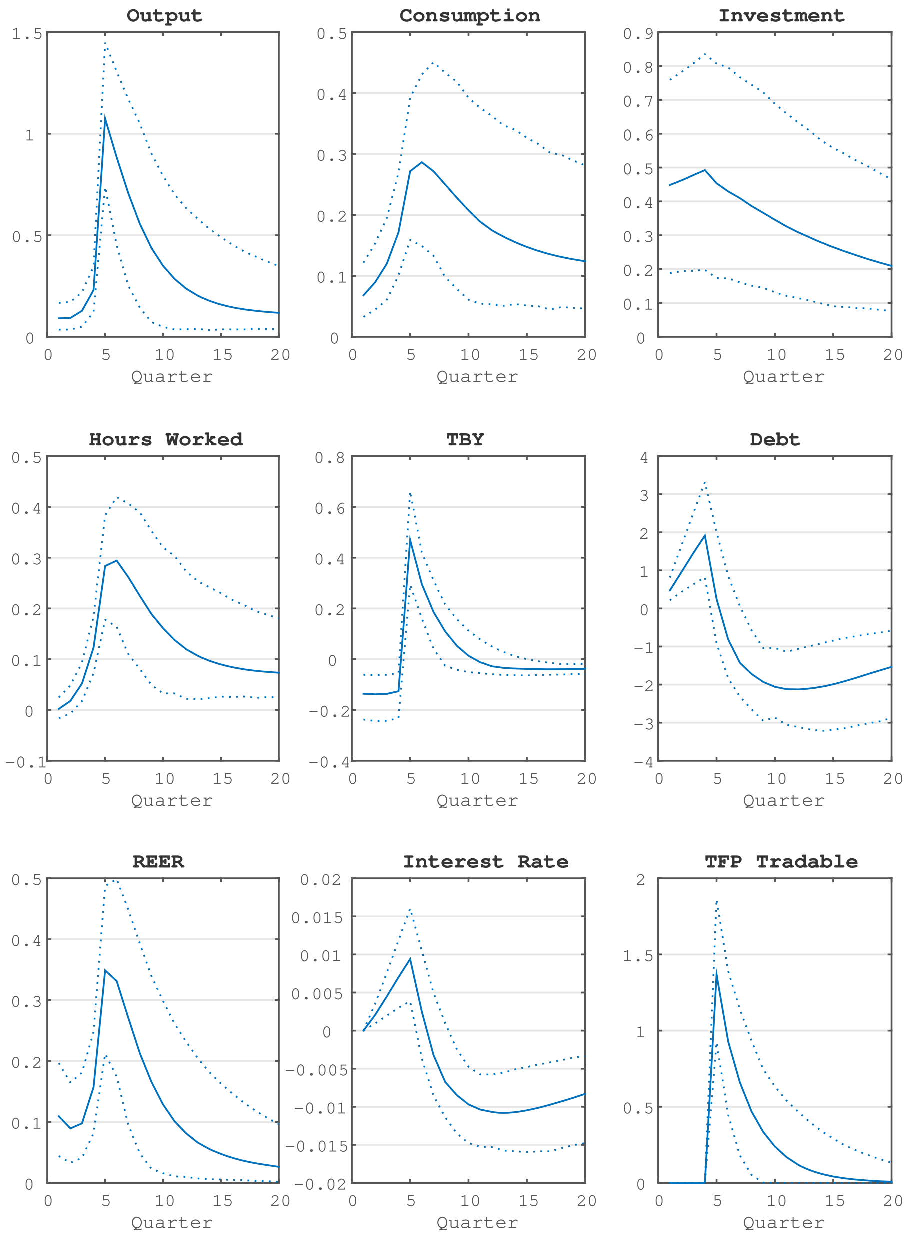
Together these facts explain the initial dynamic generated by the release of news before the shock materializes. Once the shock takes place, the model dynamic resembles standard responses following an unanticipated shock to commodity prices, that is higher output, consumption, investment and hours worked. The domestic interest rate falls, as higher commodity prices depress the country-specific interest rate spread (Fernández *et al.*, 2018).

Therefore, our results show that anticipated movements in commodity prices (news shocks) can trigger aggregate fluctuations even before the commodity price display a change from its steady-state level. In addition, the results show that the dynamic is generated mostly by changes in the amount of capital that is accumulated before the fundamental shock materializes, a result also shown in Jaimovich and Rebelo (2009) and Fornero *et al.* (2016). Our findings suggest that, in the context of the model presented here, in an environment where agents are forward-looking and news about a future change in commodity price is revealed in advance, these signals might play a significant role in explaining fluctuations in small open economies.

Figures 7–12 present the IRFs of output, consumption, investment, hours worked, trade balance-to-output ratio and debt position to one-standard-deviation news TFP shock revealed with 4 and 8 periods in advance in the Tradable, Non-Tradable and Commodity sectors. At impact, news about future productivity improvements engenders a positive response in output, consumption, investment and hours worked. Firms have the incentive to increase the capital stock in response to higher productivity in the future partly due to the presence of capital adjustment costs. The debt position expands as firms must hold a larger amount of working capital and, in consequence, the country-specific interest rate will increase. Higher investment and consumption lead to a deterioration of the trade balance-to-output ratio.

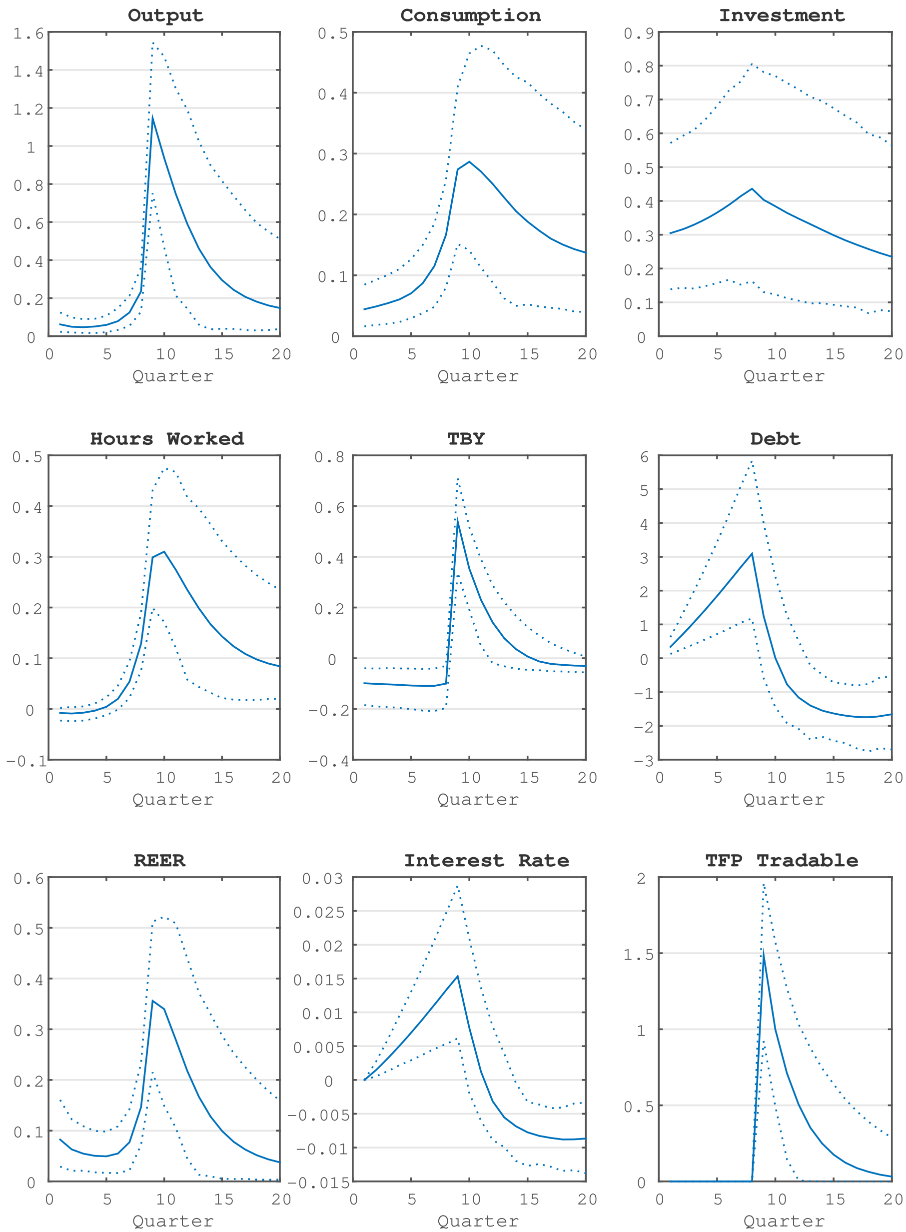
5.4 Unanticipated shocks

Figure 13 presents the IRFs of output, consumption, investment, hours worked, trade balance-to-output ratio and debt position to one-standard-deviation unanticipated shock to commodity prices. Higher commodity prices yield a positive response in output, consumption, investment and hours worked. Meanwhile, the trade balance-to-output ratio exhibits a small, but not significant deterioration at impact. However, following the shock, the trade balance-to-output ratio improves reaching a peak in the fourth quarter after the shock. Debt position improves and the domestic interest rate exhibits a decline due to higher commodity prices.



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval
Source(s): Prepared by the authors

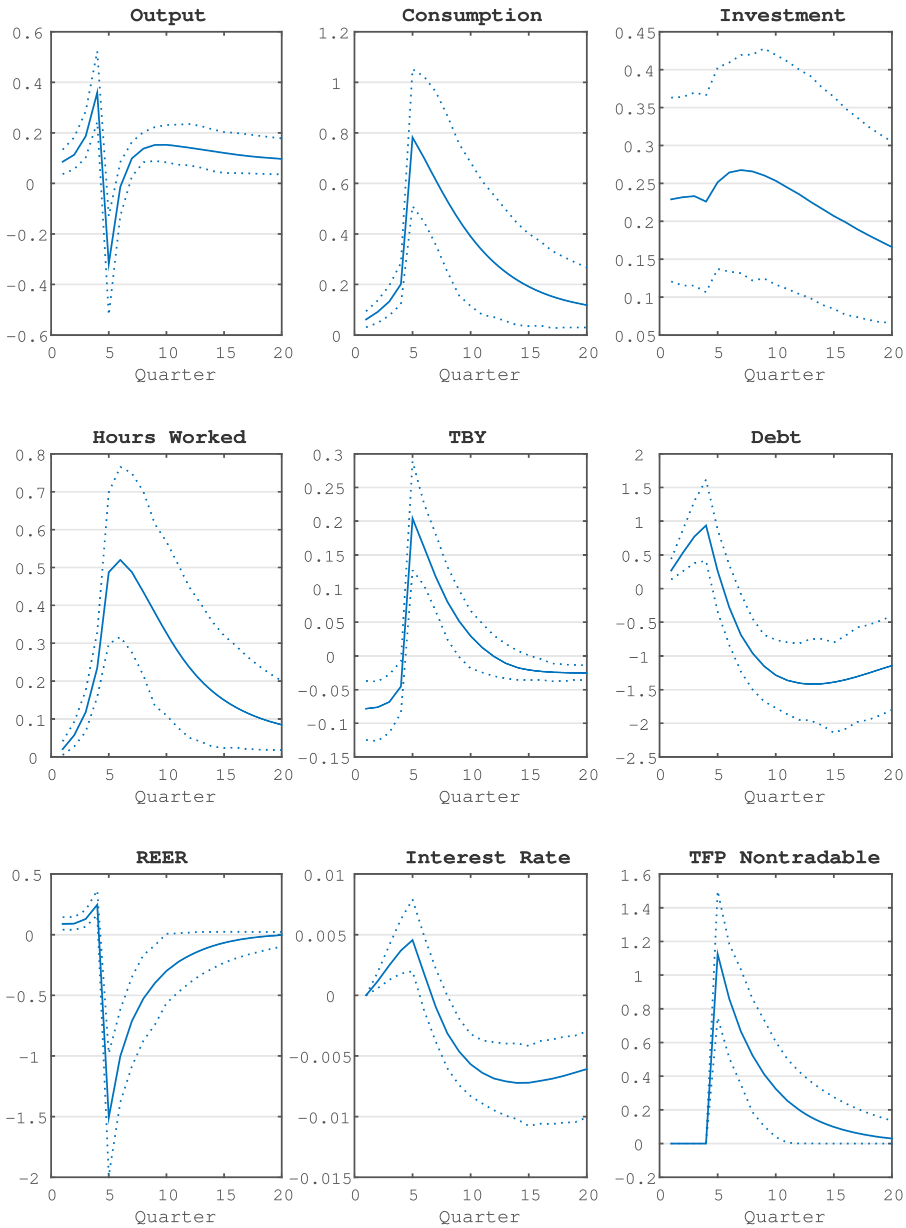
Figure 7.
News shocks in tradable TFP $t-4$



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval

Source(s): Prepared by the authors

Figure 8.
News shocks in tradable TFP $t-8$



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval
Source(s): Prepared by the authors

Figure 9.
News shocks in nontradable TFP $t-4$

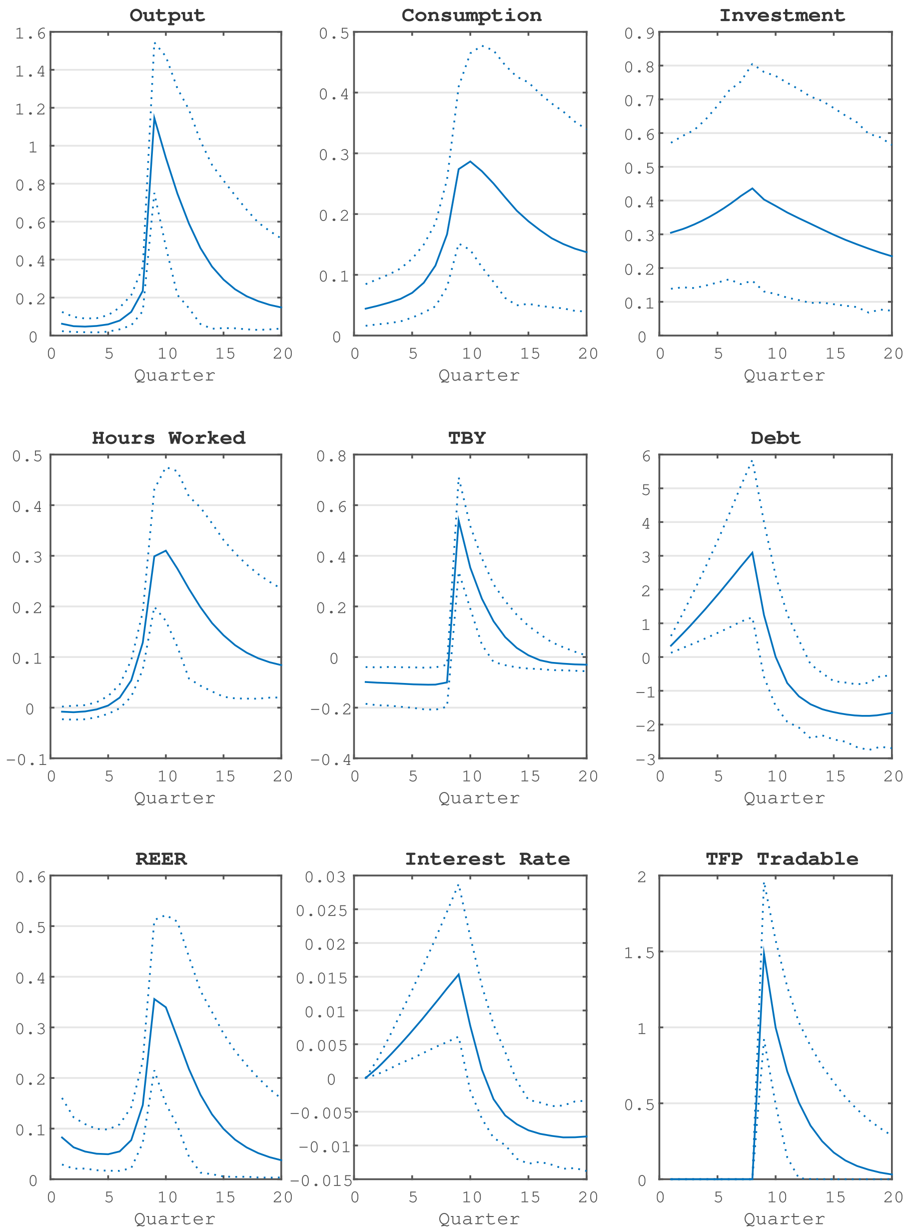
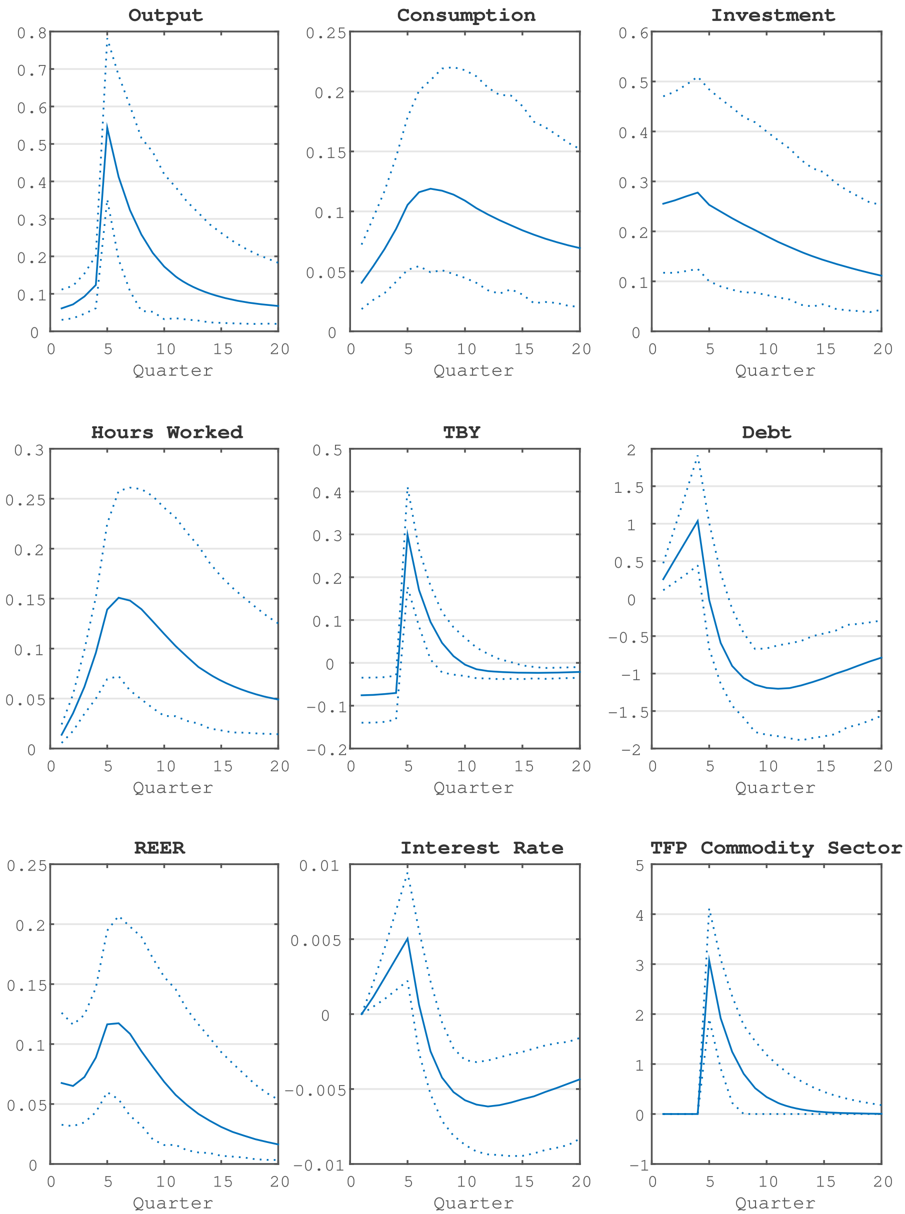


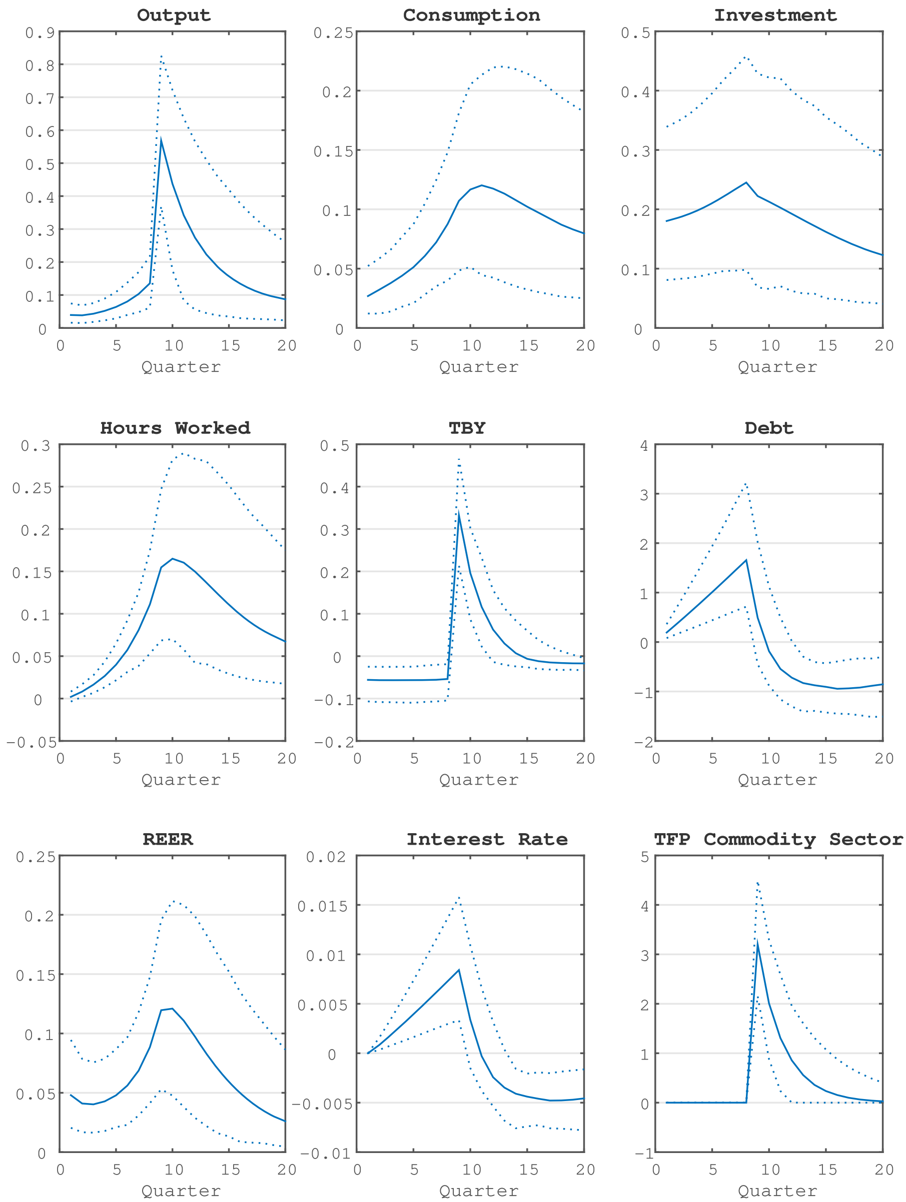
Figure 10.
News shocks in nontradable TFP $t-8$

Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval
Source(s): Prepared by the authors



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval
Source(s): Prepared by the authors

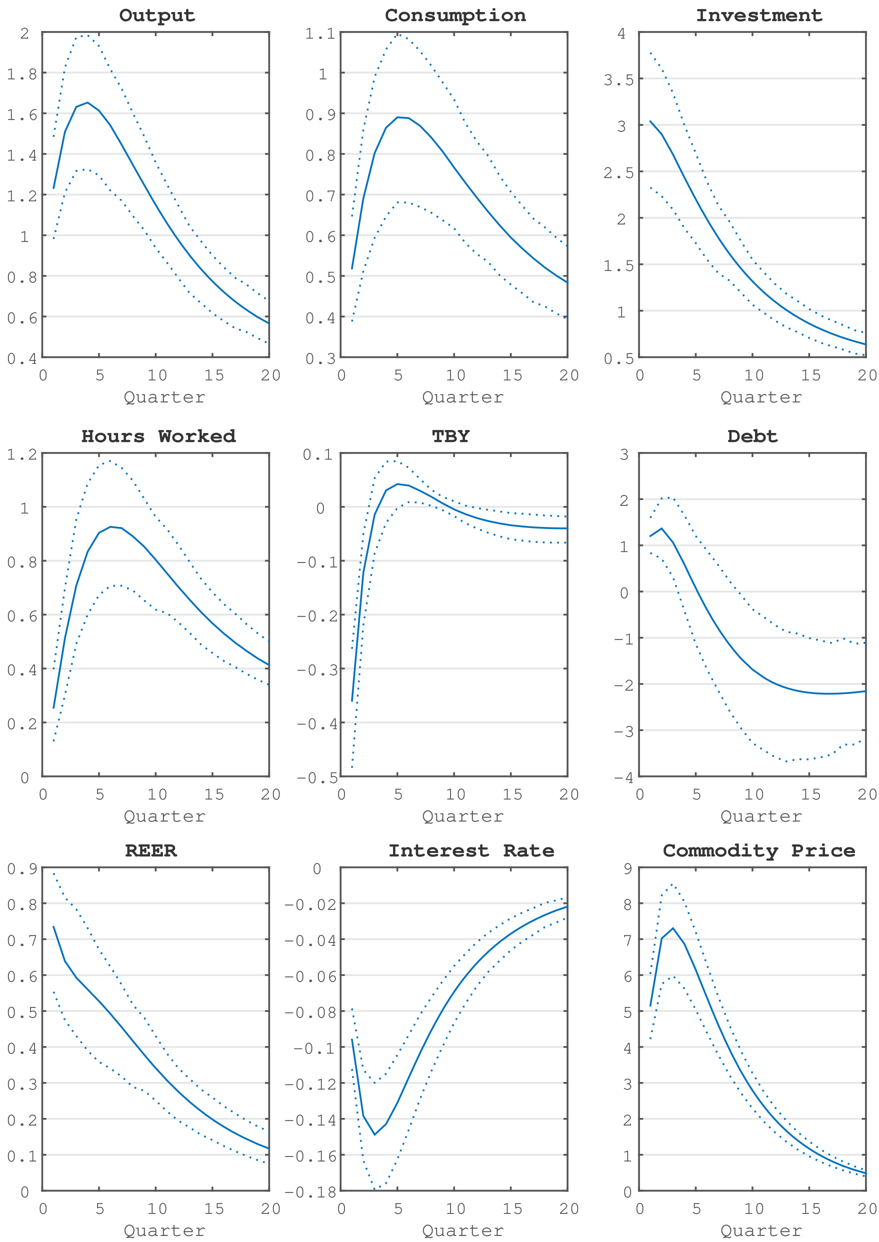
Figure 11. News shocks in commodity TFP $t-4$



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval

Source(s): Prepared by the authors

Figure 12.
News shocks in commodity TFP $t-8$



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval
Source(s): Prepared by the authors

Figure 13.
Unanticipated commodity price shock

Meanwhile, Figures 14–16 present the IRFs of output, consumption, investment, hours worked, trade balance-to-output ratio and debt position to one-standard-deviation surprise shock to TFP in the Tradable, Non-Tradable and Commodity sector, respectively. Overall, output, consumption, investment and hours worked increase after a positive TFP shock. The trade balance-to-output ratio exhibits an improvement after the shock as well as the country's debt position. As the debt position improves, the domestic interest rate exhibits a decline from its steady-state level [12]

Finally, Figure 17 displays the responses of output, consumption, investment, hours worked, the trade balance-to-output ratio and debt position to one-standard-deviation shock to the domestic interest rate. As expected output, consumption, investment and hours worked declined after the shock. Real interest rate shocks negatively affect the economy through the working capital constraint in our model (Neumeyer & Perri, 2005; Uribe & Yue, 2006). The interest rate shock exhibits low persistence and dies out quickly. This explains why most of the effect occurs at impact. The trade balance-to-output ratio is countercyclical, exhibiting an improvement after the shock.

5.5 Historical decomposition

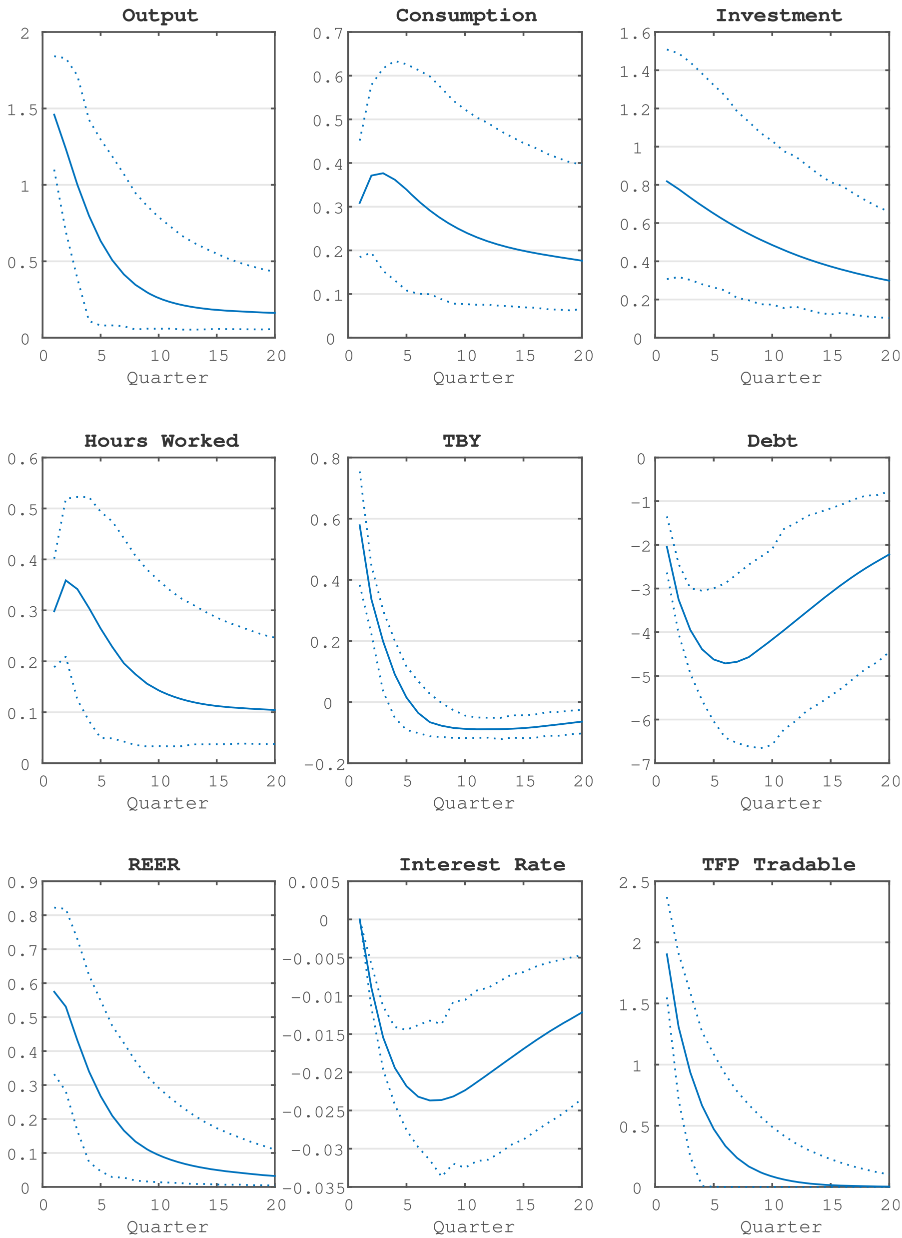
We also perform a historical decomposition exercise to shed additional light on the importance of the shocks. Figure 18 presents the historical decomposition of output. The first thing to notice is that TFP and commodity price shocks, both anticipated and unanticipated, appear as drivers of output fluctuations over time. On the other hand, interest rate shocks are of lesser importance.

In the late 1990s, commodity and TFP price shocks contributed to above-trend output, as did the later years of the 2000s. Unanticipated TFP shocks and unanticipated commodity price shocks lead to below-the-trend output in the early 2000s, despite positive TFP and commodity price news shocks. Our results also show that positive commodity price shocks and TFP shocks also helped in the output recovery after the last financial crisis. Moreover, despite positive news shocks in TFP in the last years of our sample, the combination of negative commodity price shocks and TFP shocks have pushed output down to the trend.

5.6 Additional analysis

We perform three additional analyses. First, we simulate the model by turning off all news shocks to assess the importance of unanticipated commodity price shocks, TFP shocks and interest rate shock in driving aggregate fluctuations in our model economy in contrast to our baseline model. Second, we check whether the importance of commodity price shocks is driven by the AR(2) specification used in the baseline model. Finally, we turn off the parameter that governs the interest rate sensitivity to commodity price movements to assess the importance of this parameter to our analysis.

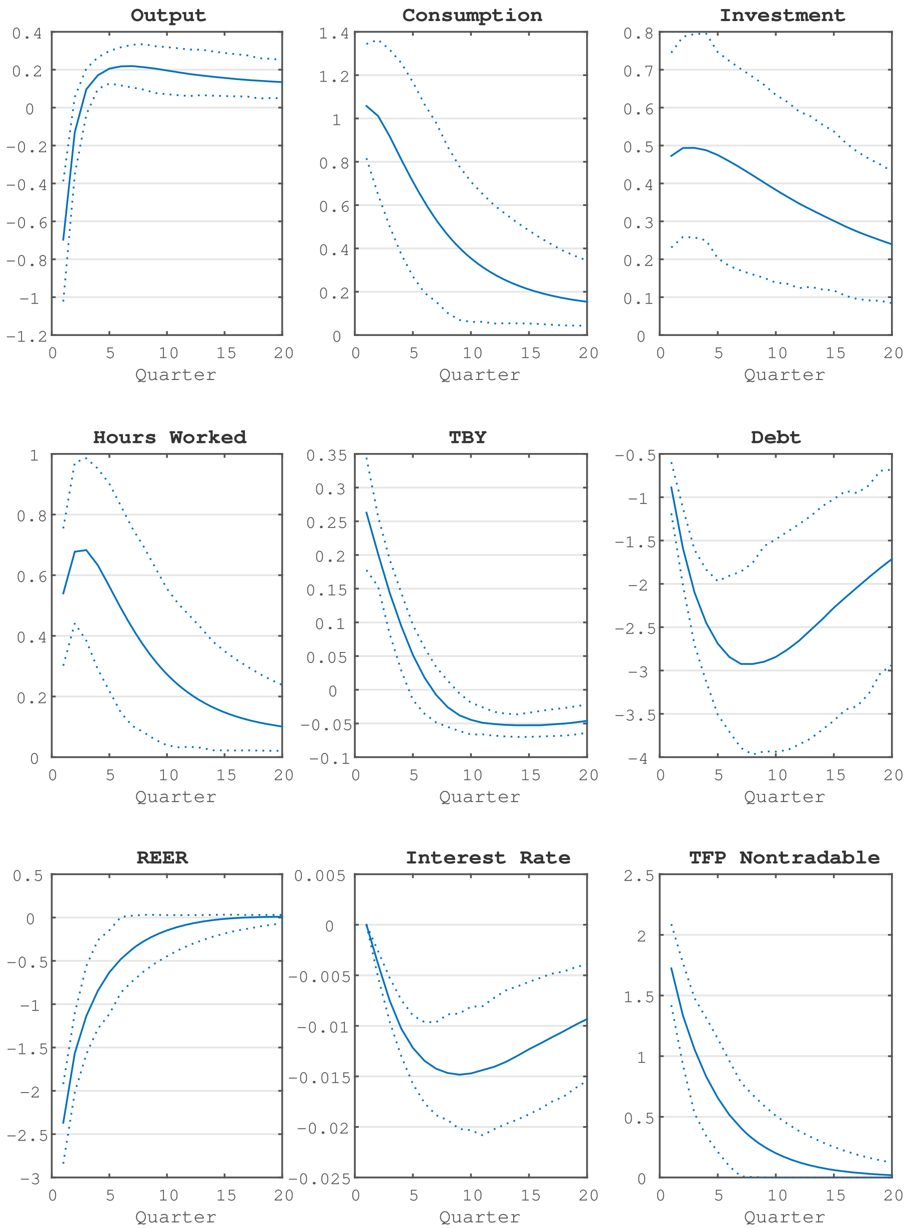
5.6.1 Model without news shocks. Table 7 presents the FEVD of real output, consumption, investment, hours and the trade-balance-to-output ratio in a model without news shocks. We keep all parameters as in the baseline model and turn off all news shocks. The FEVD results show that unanticipated commodity price shocks are the main driver of output aggregate fluctuations, accounting for 2/3 of output variance at the 32-quarter horizon. A similar result holds for consumption (54%), investment (72%) and hours (66%). On the other hand, unanticipated TFP shocks account for 23% of aggregate output, 37% of consumption and roughly 14% of investment fluctuations. However, this shock accounts for half of the trade-balance-to-output ratio fluctuation at the 32-quarter horizon. Meanwhile, interest rate shocks explain roughly 40% of the trade-balance-to-output ratio. Drechsel and Tenreyro (2018) also highlight the importance of interest rate shocks in accounting for fluctuations in the trade-balance-to-output ratio.



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% Highest Posterior Density interval

Source(s): Prepared by the authors

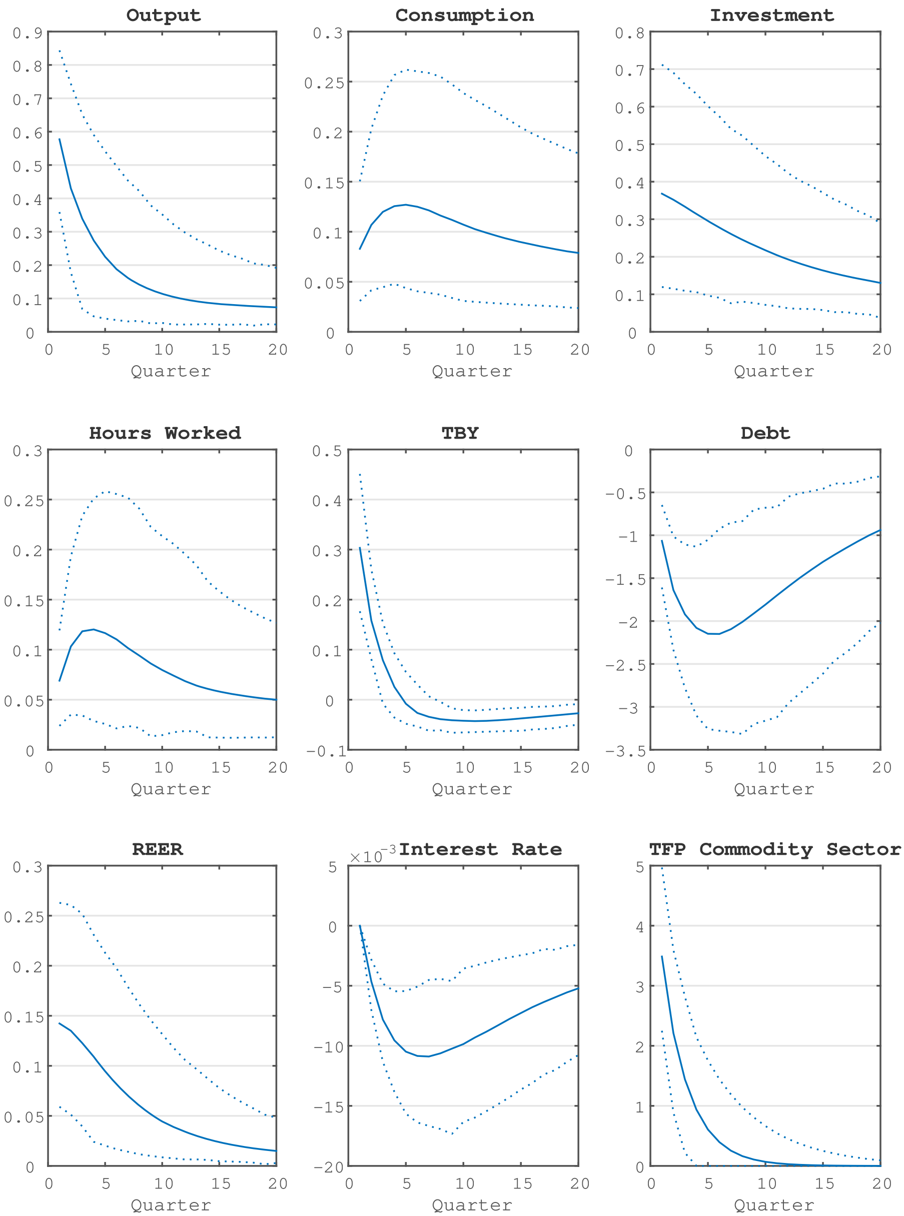
Figure 14.
Unanticipated tradable TFP shock



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% highest posterior density interval

Source(s): Prepared by the authors

Figure 15.
Unanticipated nontradable TFP shock



Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% highest posterior density interval
Source(s): Prepared by the authors

Figure 16.
Unanticipated commodity TFP shock

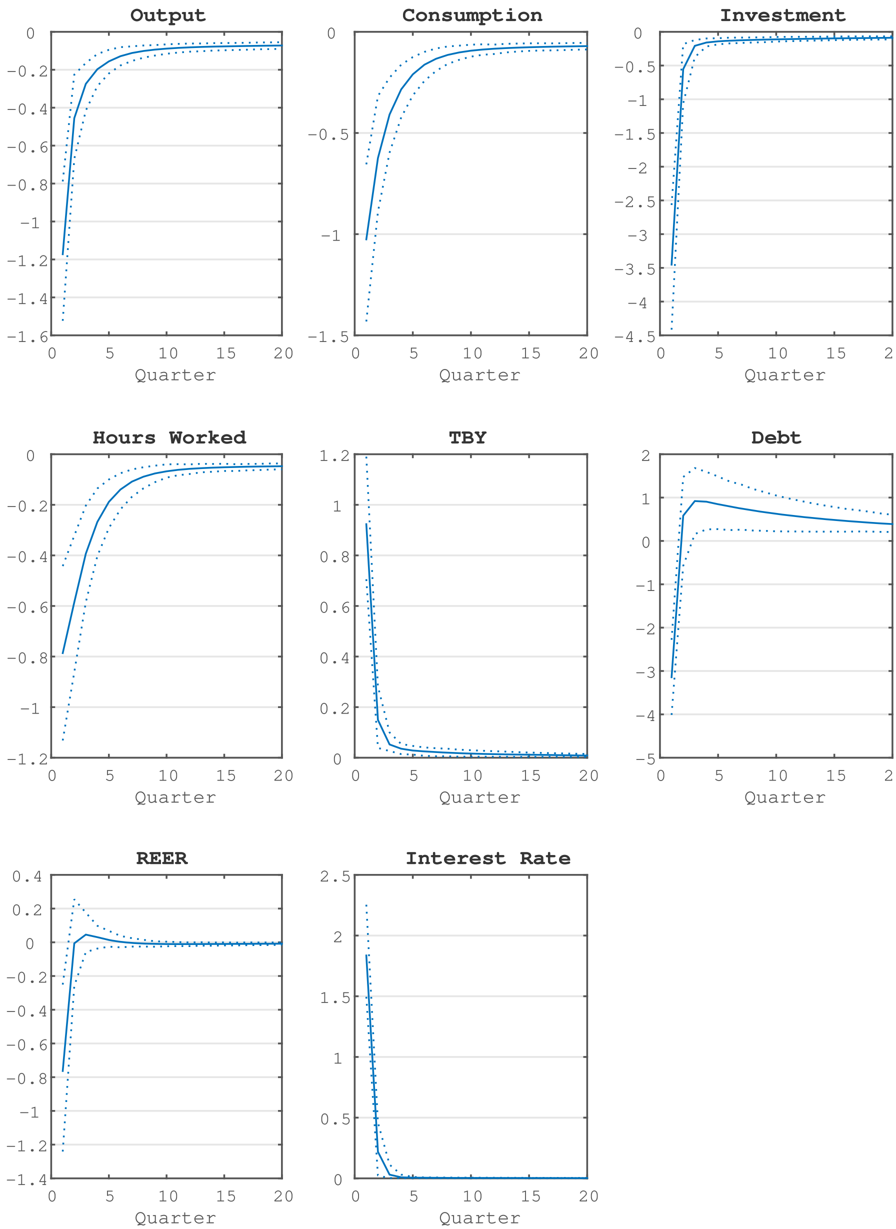
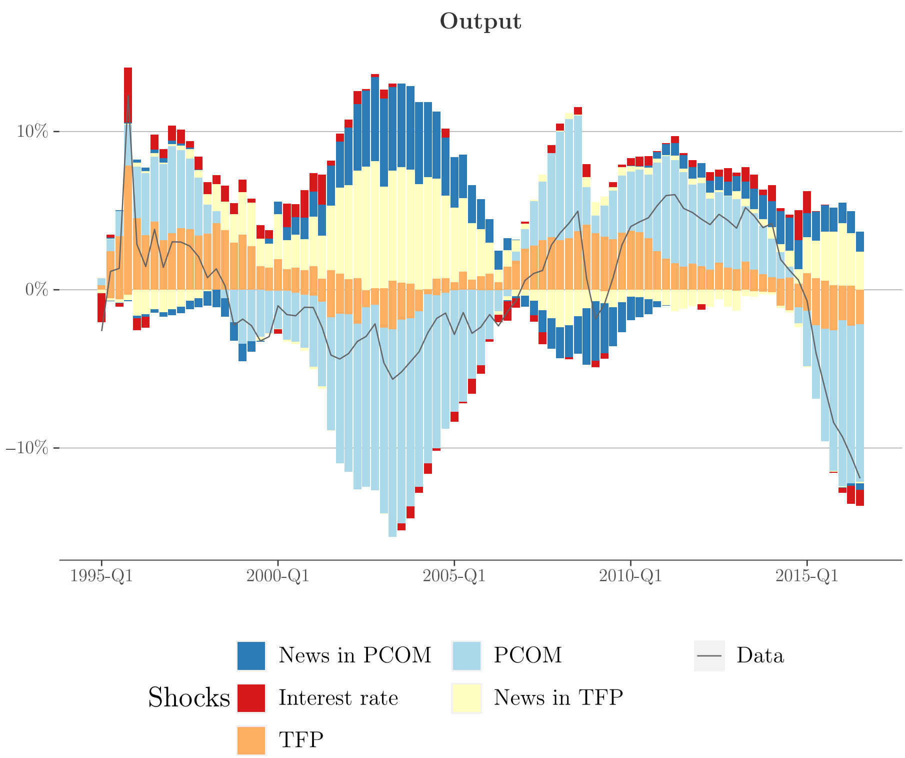


Figure 17.
Unanticipated country-specific interest rate shock

Note(s): All variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from the Bayesian posterior estimation. The blue dotted lines represent the 68% highest posterior density interval
Source(s): Prepared by the authors



Note(s): PCOM and TFP stand for Commodity Price and Total Factor Productivity, respectively. All results are expressed in percent deviations from steady-state. The bar plots represent the mean of the posterior contribution to the historical decomposition of the Output
Source(s): Prepared by the authors

Figure 18. Historical shock decomposition

These results indicate that a non-negligible part of the variance of the main aggregate variables attributable to unexpected shocks in a model without news shocks may be due to omitted news shocks in commodity prices and TFP.

5.6.2 Model with a different commodity price specification. Table 8 presents the FEVD of real output, consumption, investment, hours and the trade-balance-to-output ratio in a model with an alternative commodity price specification. In our baseline model, we estimate an AR(2) process as Shousha (2016) and Drechsel and Tenreyro (2018) and use the estimation results to calibrate the persistence parameters of the commodity price process. Therefore to check whether our results are robust to a different specification of the commodity prices, we estimate an AR(1) process and use the estimated persistence parameter in our model. We keep all the other parameters as in the baseline model. Overall, the main results remain unchanged.

5.6.3 Model without feedback in the interest rate specification. In our baseline model, the interest rate process includes a term that captures in a reduced form fashion the relationship between commodity prices and the country's real interest rate (Fernández *et al.*, 2018; Shousha, 2016; Drechsel & Tenreyro, 2018). To assess the importance of this relationship to our results, we perform a model simulation where we set the parameter governing the interest rate sensitivity to commodity price movements to zero, i.e. $v^C = 0$, while keeping all other parameter values as in the baseline model. We then compute the impulse responses to an

Variable	PCOM	News in PCOM	Innovation TFP	News in TFP	Interest rate
Horizon = 2 quarters					
$\widehat{Y}_t$	37.06	0	47.95	0	14.98
$\widehat{C}_t$	15.94	0	54.78	0	29.28
$\widehat{I}_t$	56.15	0	6.73	0	37.13
$\widehat{L}_t$	13.9	0	46.45	0	39.65
$\widehat{TBY}_t$	8.05	0	43.95	0	48
Horizon = 4 quarters					
$\widehat{Y}_t$	51.73	0	39.02	0	9.25
$\widehat{C}_t$	25.99	0	54.61	0	19.41
$\widehat{I}_t$	66.37	0	8.39	0	25.24
$\widehat{L}_t$	30.72	0	46.4	0	22.88
$\widehat{TBY}_t$	7.66	0	46.85	0	45.49
Horizon = 6 quarters					
$\widehat{Y}_t$	59.89	0	33	0	7.1
$\widehat{C}_t$	33.74	0	51.27	0	14.98
$\widehat{I}_t$	69.86	0	9.43	0	20.7
$\widehat{L}_t$	43.2	0	40.95	0	15.84
$\widehat{TBY}_t$	7.83	0	46.88	0	45.3
Horizon = 8 quarters					
$\widehat{Y}_t$	64.51	0	29.43	0	6.07
$\widehat{C}_t$	39.28	0	48.05	0	12.68
$\widehat{I}_t$	71.3	0	10.23	0	18.47
$\widehat{L}_t$	51.17	0	36.31	0	12.51
$\widehat{TBY}_t$	7.81	0	47.3	0	44.88
Horizon = 16 quarters					
$\widehat{Y}_t$	70.55	0	24.64	0	4.81
$\widehat{C}_t$	49.31	0	41.19	0	9.5
$\widehat{I}_t$	72.3	0	12.24	0	15.47
$\widehat{L}_t$	62.68	0	28.63	0	8.69
$\widehat{TBY}_t$	7.6	0	50.34	0	42.07
Horizon = 32 quarters					
$\widehat{Y}_t$	72.03	0	23.55	0	4.43
$\widehat{C}_t$	54.3	0	37.6	0	8.1
$\widehat{I}_t$	72.12	0	13.66	0	14.21
$\widehat{L}_t$	66	0	26.41	0	7.59
$\widehat{TBY}_t$	8.4	0	51.59	0	40.01

Note(s): PCOM and TFP stand for Commodity price and Total Productivity factor, respectively. The relative contribution of each group of shocks is expressed as percentage points of the corresponding conditional variance decomposition implied by the model. TFP is the sum of the three productivity shocks in each sector
Source(s): Prepared by the authors

Table 7.
Forecast error variance decomposition - Model with no News Shocks

Table 8. Forecast error variance decomposition - Model with an AR(1) Commodity price process

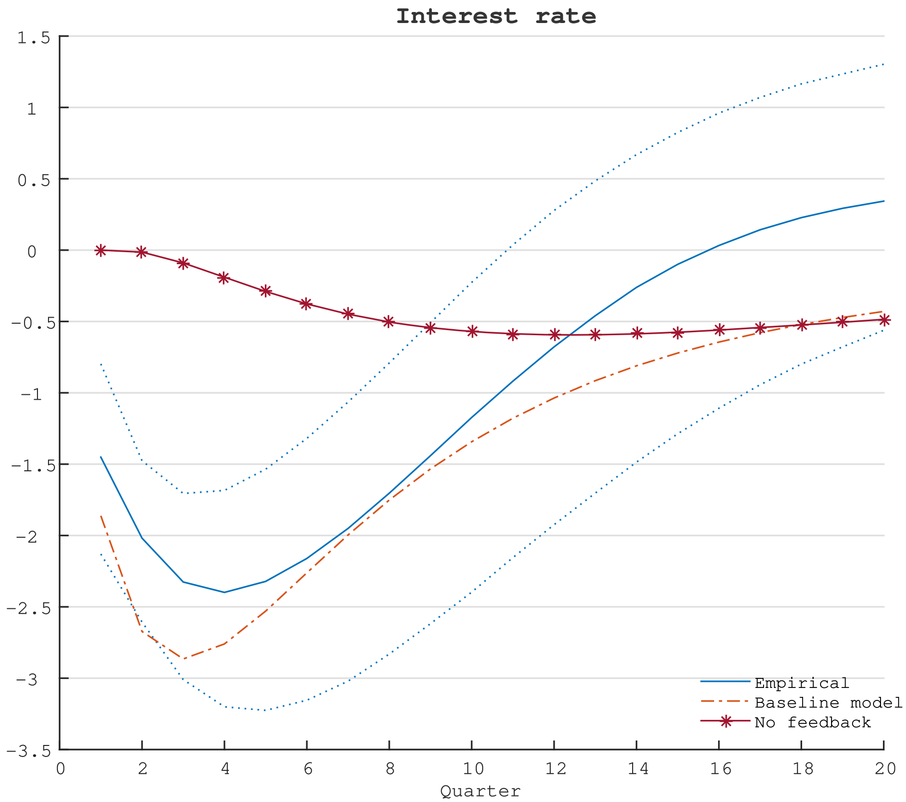
Variable	PCOM	News in PCOM	Innovation TFP	News in TFP	Interest rate
Horizon = 2 quarters					
$\widehat{Y}_t$	28.48	1.19	53.07	0.69	16.57
$\widehat{C}_t$	11.69	1.47	56	0.91	29.93
$\widehat{I}_t$	43.18	8.67	6.88	3.32	37.96
$\widehat{L}_t$	7.61	0.12	49.6	0.32	42.35
$\widehat{TBY}_t$	6.15	12.07	36.78	4.83	40.16
Horizon = 4 quarters					
$\widehat{Y}_t$	37.43	1.77	47.12	2.5	11.18
$\widehat{C}_t$	18.42	2.43	56.68	2.33	20.14
$\widehat{I}_t$	50.45	12.12	8.21	4.56	24.67
$\widehat{L}_t$	17.76	0.84	52.59	2.89	25.93
$\widehat{TBY}_t$	7.97	19.54	33.06	7.37	32.09
Horizon = 6 quarters					
$\widehat{Y}_t$	38.68	4.48	35.38	13.86	7.61
$\widehat{C}_t$	21.57	3.5	47.52	13.51	13.89
$\widehat{I}_t$	52.31	14.83	8.61	5.35	18.9
$\widehat{L}_t$	24.47	2.58	43.03	13.28	16.64
$\widehat{TBY}_t$	7.41	18.7	25.77	23.22	24.9
Horizon = 8 quarters					
$\widehat{Y}_t$	41.44	6.72	29.65	16.07	6.11
$\widehat{C}_t$	24.58	4.88	41.95	17.52	11.07
$\widehat{I}_t$	52.54	17.05	8.71	6	15.71
$\widehat{L}_t$	29.32	4.89	35.56	17.99	12.25
$\widehat{TBY}_t$	7.36	20.76	24.17	24.78	22.93
Horizon = 16 quarters					
$\widehat{Y}_t$	41.82	17.07	17.51	20.17	3.42
$\widehat{C}_t$	29.42	10.28	28	25.85	6.46
$\widehat{I}_t$	51.75	21.63	8.62	7.08	10.91
$\widehat{L}_t$	35.75	15.17	19.88	23.18	6.03
$\widehat{TBY}_t$	5.96	16.91	21.34	37.97	17.83
Horizon = 32 quarters					
$\widehat{Y}_t$	44.87	23.68	13.37	15.56	2.51
$\widehat{C}_t$	35.72	15.94	22.18	21.4	4.78
$\widehat{I}_t$	51.53	23.52	8.55	7.52	8.89
$\widehat{L}_t$	41.25	23.48	14.17	17.02	4.07
$\widehat{TBY}_t$	5.85	17.73	21.92	37.49	17

Note(s): PCOM and TFP stand for Commodity price and Total Productivity factor, respectively. The relative contribution of each group of shocks is expressed as percentage points of the corresponding conditional variance decomposition implied by the model. TFP is the sum of the three productivity shocks in each sector
Source(s): Prepared by the authors

unanticipated commodity price shock under this alternative formulation and compare the model responses to the same shock under the baseline formulation. Figure 19 presents the impulse responses. We also present empirical impulse responses from a Structural Vector Autoregressive (SVAR) model. Our subjacent identifying assumption is that commodity prices are not affected by any other variable in the system [13].

The main result is that while the real interest rate response is in line with the empirical pattern in the baseline model, in the alternative formulation, the real interest rate response misses the empirical pattern. The real interest rate exhibits a small decline due to the sensitivity of the interest rate to the country's debt level. As Figure 13 shows, after an unanticipated commodity price shock, the debt level declines which in turn reduces the interest rate. Therefore, the introduction of the term that captures the impact of commodity price movements in the interest rate equation helps the model replicate the behavior observed in the data.

We also implement a FEVD exercise under the alternative formulation where there is no feedback in the interest rate equation. Table 9 presents the FEVD of real output,



Note(s): Variables are expressed in percent deviations from steady-state. The blue solid lines represent median responses from an SVAR estimation. The blue dotted lines represent the 68% highest posterior density interval. The orange dash-dotted line is the interest rate response in the baseline model. The red starred line is the interest rate response in the model without the feedback of commodity prices

Source(s): Prepared by the authors

Figure 19.
Interest rate response to an unanticipated commodity price shock

Variable	PCOM	News in PCOM	Innovation TFP	News in TFP	Country interest rate
Horizon = 2 quarters					
$\widehat{Y}_t$	26.66	0.7	54.82	0.71	17.12
$\widehat{C}_t$	5.15	0.81	60.65	0.98	32.41
$\widehat{I}_t$	24.29	5.3	10.05	4.87	55.51
$\widehat{L}_t$	5.97	0.22	50.43	0.32	43.06
$\widehat{TBY}_t$	3.24	5.61	40.99	5.4	44.77
Horizon = 4 quarters					
$\widehat{Y}_t$	39.92	1.15	45.67	2.42	10.83
$\widehat{C}_t$	9.65	1.46	63.65	2.63	22.62
$\widehat{I}_t$	32.62	7.96	13.03	7.25	39.15
$\widehat{L}_t$	15.32	1.1	54.01	2.96	26.62
$\widehat{TBY}_t$	9.54	8.96	37.16	8.27	36.07
Horizon = 6 quarters					
$\widehat{Y}_t$	41.52	3.98	33.92	13.29	7.3
$\widehat{C}_t$	12.7	2.13	54.02	15.38	15.79
$\widehat{I}_t$	36.37	9.95	14.06	8.76	30.87
$\widehat{L}_t$	21.62	2.78	44.58	13.77	17.24
$\widehat{TBY}_t$	9.72	9.63	28.12	25.35	27.18
Horizon = 8 quarters					
$\widehat{Y}_t$	42.98	7.02	28.6	15.5	5.89
$\widehat{C}_t$	15.64	3.12	48.3	20.19	12.75
$\widehat{I}_t$	38.1	11.7	14.37	9.89	25.93
$\widehat{L}_t$	25.63	5.2	37.38	18.9	12.88
$\widehat{TBY}_t$	9.38	12.56	26.25	26.92	24.9
Horizon = 16 quarters					
$\widehat{Y}_t$	37.39	19.42	18.4	21.2	3.59
$\widehat{C}_t$	20.45	7.72	33.35	30.79	7.69
$\widehat{I}_t$	39.81	16.22	14.25	11.7	18.01
$\widehat{L}_t$	27.72	15.5	22.99	26.81	6.98
$\widehat{TBY}_t$	7.31	18.09	20.63	36.72	17.25
Horizon = 32 quarters					
$\widehat{Y}_t$	37.4	23.09	16.79	19.54	3.16
$\widehat{C}_t$	25.27	12.57	28.52	27.49	6.14
$\widehat{I}_t$	40.24	18.74	14.05	12.35	14.61
$\widehat{L}_t$	29.66	20.94	19.86	23.83	5.7
$\widehat{TBY}_t$	9.44	17.72	20.89	35.74	16.2

Note(s): PCOM and TFP stand for Commodity price and Total Productivity factor, respectively. The relative contribution of each group of shocks is expressed as percentage points of the corresponding conditional variance decomposition implied by the model. TFP is the sum of the three productivity shocks in each sector
Source(s): Prepared by the authors

Table 9.
Forecast error variance decomposition - Model without feedback in the interest rate

consumption, investment, hours and the trade-balance-to-output ratio the results. Overall the main results remain unchanged.

6. Conclusion

In this paper, we develop a multi-sector small open economy model with endogenous commodity production and several real rigidities to assess the importance of a new driver of aggregate fluctuations in emerging economies: news shocks in commodity prices. The underlying hypothesis is that in an environment where agents are forward-looking, news about future changes in fundamentals engender earlier responses in economic variables, leading to aggregate fluctuations even before the news materializes. The novelty in our approach is to consider news shocks in commodity prices.

The model also features an interest rate process that responds to commodity prices in line with recent evidence that shows that periods of high commodity prices coincide with low levels of country spreads (Bastourre *et al.*, 2012; Fernández *et al.*, 2018). Therefore, the effects of a commodity price shock can be amplified through movements in interest rates in opposite directions, deepening the impacts of commodity price shocks on the rest of the economy through changes in financial conditions. We show that allowing this feedback from commodity price movements to the interest rate faced by the domestic economy in international financial markets helps the model to replicate the observed behavior in the data.

Our main result is that although unexpected shocks are still the main drivers of fluctuations, news shocks in commodity prices are a non-negligible source of fluctuations in emerging economies. At the 32-quarter horizon, for instance, this shock explains roughly 24% of aggregate output fluctuations, 16% of consumption, 24% of investment, 25% of hours worked and 25% in the trade balance-to-output ratio at the 32-quarters horizon.

We also present evidence that in response to good news in commodity prices, aggregate output, consumption, investment and hours worked all increase following the shock. On the other hand, the trade balance-to-output ratio deteriorates. Consequently, news shocks in commodity prices may offer an explanation for the countercyclicality of the trade-balance-to-output ratio found in the emerging economy data (Drechsel & Tenreyro, 2018; Shousha, 2016). As it is well known emerging economies' business cycles are more volatile than in rich countries (Uribe & Schmitt-Grohé, 2017). One of the reasons is that they face a large variety of (more volatile) shocks, such as productivity disturbances (Mendoza, 1991; Garcia-Cicco *et al.*, 2010), terms of trade (Mendoza, 1995; Kose, 2002), country risk premium (Neumeyer & Perri, 2005; Uribe & Yue, 2006), commodity prices (Shousha, 2016; Drechsel & Tenreyro, 2018), among others. This paper contributes to our knowledge of the sources of fluctuations in emerging economies highlighting the importance of a new source: news shocks in commodity prices.

Given the importance of both anticipated and unanticipated commodity price shocks, policymakers should pay attention to developments in commodity markets when designing policies to attenuate the business cycles. Future research should investigate the design of optimal fiscal and monetary policies in SOE subject to news shocks in commodity prices.

Notes

1. The plausibility of the aforementioned logic has been challenged by earlier literature, which used a standard business cycle model to explore its validity. In particular, Beaudry & Portier (2004) and Beaudry & Portier (2007) were unable to replicate a boom in response to expectations of higher future total factor productivity (TFP) using variants of the neoclassical growth model. According to their findings, good news about future changes in TFP makes agents wealthier, which, in turn, leads to increased consumption and leisure. This results in a decline in labor supply, causing a reduction in output.

2. Recently, Schmitt-Grohé & Uribe (2018) show that the importance of TOT shocks in explaining business cycles in emerging economies differs considerably when using empirical and theoretical models. TOT shocks are three times stronger in the theoretical model than in the empirical VAR approach.
3. Cochrane (1994) denotes this shock as "consumption shocks". He shows that VARs estimated using simulated data from a real business cycle (RBC) model driven by contemporaneous and news shocks to technology could resemble well the corresponding responses implied by VARs on actual U.S. data.
4. Zeev *et al.* (2017) estimate country-specific VAR models for a sample of Latin American countries and find that unexpected terms of trade shocks explain an average of 23% of output fluctuation, whereas TOT news shocks explain an average of 49% in the same variable.
5. 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.
6. This type of utility function is described in Greenwood, Hercowitz, & Huffman (1988). A key feature of GHH preference is that there is no income effect on households' labor supply.
7. For simplification, we choose not to model the default decisions as this is out of the scope of this present work.
8. 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.
9. We estimate the parameters in a Near-SVAR model with Monte Carlo Integration using a recursive identification scheme. Our subjacent identifying assumption is that commodity prices are not affected by any other variable in the system.
10. We use the following commodity price indexes: Food Price Index (PFOOD), Energy (Fuel) Price Index (PNRG), Beverage Price Index (PBEVE), Metals Price Index (PMETA) and Agricultural Raw Materials Index (PRAWM).
11. The positive correlation between the model's trade-balance-to-output ratio and output is partly due to the estimated value of the investment adjustment cost parameter. When performing a counterfactual analysis by lowering the value of the parameter, the model is able to replicate the negative correlation as in the data. However, this comes at the cost of the model's failure in some other dimension.
12. An initial decline in output is observed in response to a surprise TFP shock in the non-tradable sector. Although physical output increases in all sectors, a decline in the relative price of non-tradable, p_t^N, leads to a small decline in aggregate output.
13. The model is a Near-SVAR model estimated via Monte Carlo Integration using real output, real consumption, trade balance-to-output ratio, real interest rate and real commodity price index. All data are seasonally adjusted using X-13 ARIMA-SEATS. All variables are in log deviation from a log-linear and log-quadratic trend. Except for the trade balance-to-output ratio. We also demean each variable separately.

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