How important are commodity price shocks?
A small open economy analysis

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Abstract

Commodity prices, as other external variables, play an important role for commodity-exporting economies. This paper assesses the dynamic impact of commodity prices on business cycles for a group of commodity exporters. These economies are subject to the same external shocks, therefore it is necessary to estimate their behavior simultaneously. Moreover, the impact of these shocks might be different along the sample of analysis. To cover all these features, I estimate a Panel VAR model with dynamic inter-dependencies and time varying parameters. My results show that after an increase in commodity prices, output and prices go up. For most countries, positive commodity price shocks are followed by exchange rate appreciation and improvements in the current account. Finally, I find some degree of heterogeneity across countries both in amplification and propagation.

Key words: Commodity Prices, Panel Vector Autoregressions, Bayesian Methods

1   Introduction

What drives business cycles in small open economies (SOE)? This is still an open question in the International Macroeconomics literature. The candidates include total factor productivity (TFP), foreign interest rates, external demand/supply and commodity price shocks (or more generally terms of trade). The recent large swings in country's terms of trade, mostly due to fluctuations in commodity prices, have been accompanied by strong economic fluctuations, especially in small commodity-exporting economies. Based on that, there has been a renewed interest in study the role of commodity prices on business cycle fluctuations. This paper explores the dynamic effects of commodity price shocks for a set of small commodity exporters through the estimation of a Panel VAR model with lagged inter-dependencies and time varying parameters.

According to the Real Business Cycle (RBC) school, productivity shocks account for most of business-cycle fluctuations[1]. For one instance, Aguiar and Gopinath (2007) find that non stationary total factor productivity (TFP) shocks play an important role in explaining movements at business cycle frequencies. García-Cicco et al. (2010), using a standard stochastic small open economy business cycle model, also stress the role played by TFP shocks. However, they argue that, unlike Aguiar and Gopinath (2007), the main driver for emerging economies are stationary TFP shocks.

The previous studies highlight TFP shocks, which are mainly of domestic source. However, the nature of small open economies make them subject to external (foreign) shocks too, which can also be an important source of fluctuations[2]. Among these kind of shocks, the literature has focused mainly on global interest rates and global demand/supply shocks. Neumeyer and Perri (2005) explain that the reason why emerging economies are more volatile than advanced economies is related with more pronounced fluctuations in the real interest rate faced by emerging economies. In particular, their results show that almost 30% of output volatility can be accounted by global interest rate shocks. In the same line, Uribe and Yue (2006) also study

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[1] See Mendoza (1991), Backus et al. (1992), Correia et al. (1995) and Schmitt-Grohé and Uribe (2003) for a review of the standard RBC model for small open economies.

[2] There are some works which do not find a significant contribution of foreign shocks for emerging economies. See for example Sánchez (2007), Hoffmaister and Roldós (1997) and Kose et al. (2003).

the relationship between world interest rate and business-cycle fluctuations. By considering US interest rate as the world interest rate faced by emerging economies, their findings indicate that about 20% of movements in aggregate activity are explained by US interest rate shocks. Moreover, world interest shocks affect domestic variables through their effect on country spreads, which account for almost 12% of output fluctuations. Other works which have also highlighted the major role that world interest rates play for business cycles in emerging economies are Fernández-Villaverde et al. (2011), Akinci (2013)[3].

Regarding global GDP shocks, most studies for emerging economies have focused on the role played by US or China. For example, Canova (2005) analyzes the transmission of US shocks to eight Latin American countries. Although he does not find significant impacts of US real demand or supply shocks, the study finds that US monetary shocks do induce large and significant responses for Latin American macroeconomic variables. He also finds quantitative differences between countries with floating and non-floating exchange rates, but no differences in terms of pattern of transmission. Using also Latin America data, Cesa-Bianchi et al. (2011) employ a Global VAR model to ask how the emergence of China has changed business cycles in Latin America. Their results show that the long-term impact of a China GDP shock on the average Latin America country has increased by a factor of three since the mid-1990s.

Another important external shock, specially relevant for commodity-exporting economies, are commodity prices or, more generally, terms of trade. They have received major attention since the beginning of the last decade due to the large increase it was observed in several commodity prices (fuel and metal, for example). Because of this improvement in prices, many commodity-exporting economies experienced significant positive impacts on their GDP, current accounts and other macroeconomic variables.

However, the quantitative importance of these shocks for business cycle fluctuations is still a matter of doubt. The first study on the subject was conducted by Mendoza (1995). Using a calibrated model, he shows that almost 50% of actual GDP variability was explained by terms-of-trade shocks. Kose (2002) extends the model proposed by Mendoza (1995) to consider a richer production structure and finds that these shocks explain roughly 88% of aggregate output

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[3]See Fernández and Chang (2013) for a set up combining TFP and foreign interest rate shocks.

fluctuations in small open economies. These two studies are the main reference regarding the big impact of terms-of-trade shocks. However, more recently, Schmitt-Grohé and Uribe (2018) have cast doubt about that result. They estimate structural individual VAR models for 38 poor and emerging economies and find that in fact terms of trade only represent at most 10% of GDP variability[4].

Since terms of trade and commodity prices tend to move together (see Figures 1, 2 and 3), some works have focused in the specific topic of commodity price shocks, a more primitive concept. Céspedes and Velasco (2012) study the empirical relation among commodity prices, output and investment for a group of commodity-exporting countries during periods of booms and busts (large commodity prices shocks). According to their empirical evidence, commodity price shocks have a significant impact on output and investment. Moreover, they find that the response on output depends on the degree of exchange rate flexibility and the response on investment on the degree of financial market development[5]. Gruss (2014), using a Global VAR model, also finds significant impacts of commodity prices on output growth for the Latin American and Caribbean region. Using individual VAR models, Fornero et al. (2016) study the impact of commodity prices (focusing on the case of metal prices) on sectoral investment for a group of metal-exporting economies. According to their results, an increase in commodity price produces positive and significant effects on investment, which ultimately increases real GDP (this expansion is more pronounced for countries with a greater share of commodities in their exports). The expansionary effects on investment occur mainly because of the response of investment in the commodity sector, which later spills over to the non-commodity sector investment. Other studies, like Collier and Goderis (2012), have focused not only on the short-run effects of commodity prices, but also on the long-term ones. Using a panel error correction model, they show that increases in commodity prices have unconditional positive short-run effects on output, but conditional adverse long-term effects (present in the case of non-agricultural booms in countries with poor governance).

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[4]Using also structural VAR models but for only 15 emerging countries, Aguirre (2011) finds that terms-of-trade shocks explain about 5% of output fluctuations.

[5]Using terms of trade instead of commodity prices, Broda (2004) also finds heterogeneous effects on output based on exchange rate flexibility.

Some studies that have emphasized the importance to work with theoretical and empirical models that combine commodity prices and financial variables[6]. Within the theoretical works, García-Cicco et al. (2017) develop a New Keynesian small open economy model with frictions in the domestic financial intermediation sector and a commodity sector in order to asses the contribution of financial, real and external shocks on output and investment fluctuations for Chile, Colombia, Mexico and Peru. Their results suggest that financial shocks are important drivers of output and investment fluctuations in the short run for most countries, but in the long run their contribution is small. On the other hand, a fall in commodity prices generates a negative income effect that translates into drops in consumption, investment and output, which are amplified in the presence of financial frictions and generates heterogeneity in the response of real sector variables across countries[7]. Recently, considering the negative relation between the interest rate premium and commodity prices found in the data, the DSGE models proposed by Shousha (2016), Drechsel and Tenreyro (2018) and Fernández et al. (2018) have pointed out the relevance of the country's risk premium as a amplifying channel of commodity price shocks. On the empirical side, Shousha (2016) estimates a Panel VAR and shows that commodity price shocks are an important source of business cycle fluctuations for commodity exporters and have stronger effects on real activity, credit and country interest rates in emerging countries in comparison with advanced economies. The main difference in the response between emerging and advanced economies is the response of country interest rate to these shocks and differences in working capital constraints faced by firms. According with his findings, the contribution of interest rate shocks become negligible when the model includes also commodity prices. Fernández et al. (2018) and Drechsel and Tenreyro (2018) deliver also empirical evidence

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[6]A related work is Izquierdo et al. (2008), which not only combines foreign interest rates (measured by the return of the 10 year US T-bond) and terms of trade, but also includes a measure of global GDP (measured by the industrial production index of G7 countries) and risk (measured by the spread on high yield bonds over US T-bonds). Based on a restricted Vector Error Correction Model (VECM) for an index that captures output behavior of the typical Latin American country, they find that financial variables have a higher elasticity (in absolute value) when compared with terms of trade: the risk and foreign interest rate elasticities are -0.36 and -0.33, respectively (for an increase of 100 basic points in each variable); while the terms-of-trade elasticity is 0.11 (for an increase of 1% in the variable).

[7]Another theoretical work along the same line but using terms of trade instead of commodity prices is Lubik and Teo (2005). They estimate a DSGE model for five developed and developing economies and find that world interest rate shocks are the main driving forces in small open economies while terms of trade shocks are not relevant.

on the importance of commodity prices for aggregate fluctuations based on the estimation of individual VAR models for each of the countries on their samples. Unlike Shousha (2016), the VAR specification of Fernández et al. (2018) and Drechsel and Tenreyro (2018) do not consider directly interest rates in their set up. However, they present regression results that show the negative correlation between country's risk premium and commodity prices[8].

This paper makes an empirical contribution by estimating the impact of commodity prices on real and financial variables through a Panel VAR which features cross-country lagged inter-dependencies. The model follows the approach developed by Canova and Ciccarelli (2009) and allows for common, country-specific and variable-specific indicators summarizing spillover effects across countries and variables[9].

As in Shousha (2016), the model is estimated for a group of emerging (Brazil, Chile, Colombia, Mexico, Peru and South Africa) and advanced (Australia, Canada, New Zealand and Norway) small commodity exporters. I consider commodity prices instead of terms of trade because the exogenous assumption of terms of trade, usually employed by the previous works, might not be appropriate for all the countries in my sample. As stressed by Bodenstein et al. (2018), to assume that terms of trade are exogenous seems only plausible for developing economies, which tend to have a small and homogeneous set of exportable goods. However, advanced commodity exporters present a more pronounced difference between the commodity and non-commodity traded goods sector. Along the same line, Shousha (2016) explains the reasons why a commodity export price index is preferred over the typical terms of trade index (ratio of export and import unit value indices): (i) unit value indices are subject to biases that produce important discrepancies between them and price indices[10], (ii) unit value indices are more possible to be endogenous with respect to country-specific shocks than global commodity prices, and (iii) nominal rigidity and incomplete pass-through prevent terms of trade indices from correctly incorporate contemporaneous shocks that induce immediate effects on the exchange rate[11].

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[8] Fernández et al. (2018) and Drechsel and Tenreyro (2018) do not make a distinction between emerging and advanced economies as Shousha (2016) because their sample of countries is more homogeneous. For instance, Fernández et al. (2018) works with four Latin American countries (Brazil, Chile, Colombia and Peru) and Drechsel and Tenreyro (2018) with Argentina as a representative small commodity exporting economy.

[9] See also Canova and Ciccarelli (2013).

[10] See Silver (2009) for a detailed explanation of the sources of bias for unit value indices.

[11] This feature has been noted by Chen and Rogoff (2003).

I depart from Shousha (2016) along two lines. The fist difference is that I do not use a country specific export price index. Instead, I work with the IMF Commodity Price Index as an exogenous variable common to all countries. As mentioned by García-Cicco et al. (2017), using a country specific price index makes the commodity price shock not completely comparable among countries. Moreover, Fernández et al. (2018) find that country specific commodity price indices share an important common global factor. According with their results, commodity price shocks account for a median of 42% of output variance, with common global factors representing 73% of that response. In that sense, modelling commodity prices as a exogenous common external shock seems more appropriate. Furthermore, since all countries are subject to the same external shock (i.e. the commodity price index I employ is common to all countries), it is necessary to estimate country's behavior simultaneously. For that reason, unlike the previous works cited which rely on the estimation of individual VAR models, I work using a Panel VAR[12]. The second difference with Shousha (2016) is associated with the methodology used to estimate the Panel VAR. He estimates his Panel VAR model by pooling the data and using the Least Square Dummy Variable (LSDV) estimator, which imposes common parameters to every country. I set up a more flexible Panel VAR approach by allowing inter-linkages among countries and variables as well as time varying parameters[13].

The rest of the paper is organized as follows. Section 2 presents a set of stylized facts. In particular, the relation between commodity prices and macroeconomic variables for the sample of countries I use. Section 3 describes the econometric model, section 4 describes the estimation procedure, section 5 discusses the main results, and section 6 concludes.

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[12]Besides the works already cited which estimate a VAR for each country, there are several other studies which have studied the impact of commodity prices (or terms of trade) by just focusing on a particular country of my sample. See Jääskelä and Smith (2011), Rees (2013), Atkin et al. (2014), Knop and Vespignani (2014), Kulish and Rees (2017) (Australia); Benguria et al. (2018) (Brazil); Dib (2008), DePratto et al. (2009), Vasishtha and Maier (2013), Charnavoki and Dolado (2014) (Canada); Medina and Soto (2007), Medina and Naudon (2012), Pedersen (2015), Medina and Soto (2016), Roch (2017), Fornero and Kirchner (2018) (Chile); Hernández (2013), Toro-Córdoba et al. (2015), Cárdenas-Hurtado et al. (2018) Roch (2017) (Colombia); Medina et al. (2007), Karagedikli (2012) (New Zealand); Bergholt (2015), Bjørnland and Thorsrud (2016), Bergholt et al. (2017) (Norway); Han (2014), Roch (2017) (Peru); and Hove et al. (2015) (South Africa).

[13]An alternative approach would be to use the modified (bias-corrected) LSDV estimator proposed by Hahn and Kuersteiner (2002). However, that estimator still has the disadvantage of not allowing inter-linkages across countries and variables.

2   Stylized facts

In the previous section I argued that my empirical model will use a common commodity price index, computed by the IMF, instead of the usual terms of trade index available for each country. In this section I show that indeed terms of trade and commodity prices tend to move together. Figure 1 shows the terms of trade of emerging and advanced economies along with the IMF commodity price index. As it can be seen, both variables move together and share on average the same pattern.

Figure 1: Terms of Trade and IMF Commodity Price Index (1995 = 100)
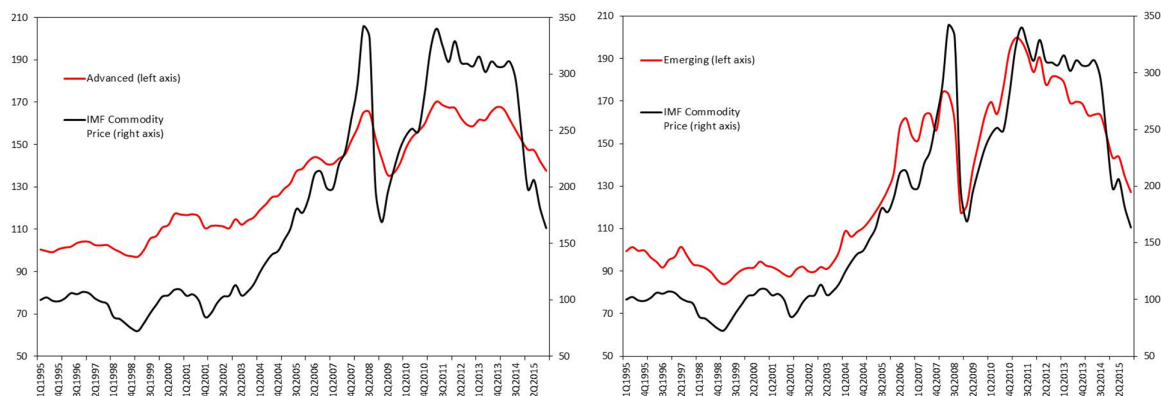
Note: The terms of trade index for each country group (emerging and advanced) is computed as the simple average of the terms of trade index of the countries that belong to each group.

Figure 1 only gives the average pattern of co-movement between terms of trade and commodity prices. To inspect further between this relationship, Figure 2 plots each country's terms of trade and the commodity price index. Although we saw the average profile is similar, there is some dispersion inside the two groups. However, all series show the upward trending that began at the end of 2001 and the drop in the second half of 2008. So, Figure 2 tells us that the ups and downs of the IMF commodity price index does reflect on average the individual patterns of each country terms of trade.

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Figure 2: Country's Terms of Trade and IMF Commodity Price Index (1995 = 100)
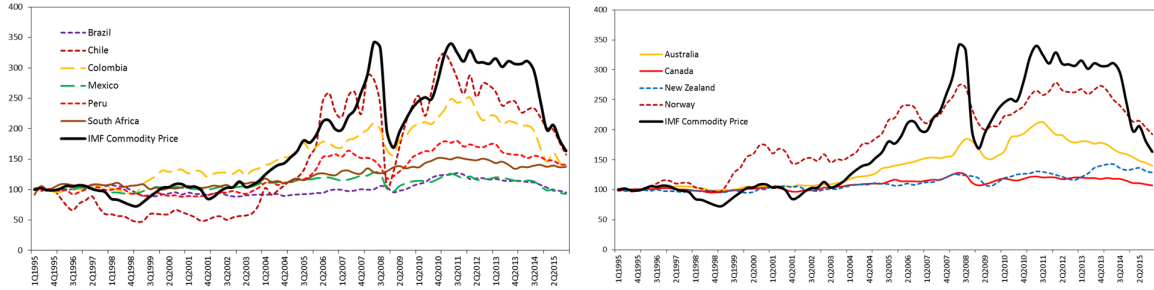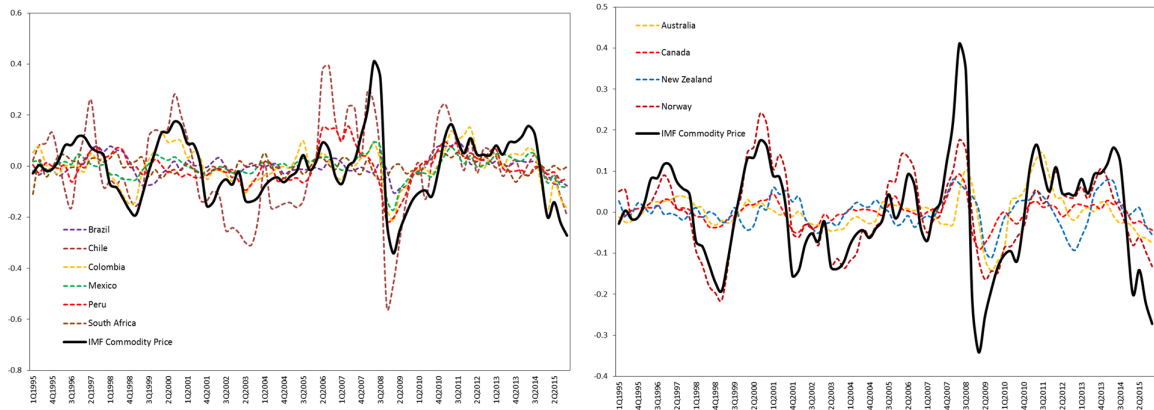

Figure 3: Country's Terms of Trade Indices and IMF Commodity Price Index (1995 = 100)
(Cyclical Component)

This last feature can be analyzed more in detail with Figure 3, which presents the cyclical component of each country's terms of trade and the commodity price index computed using the Hodrick-Prescott filter. Within the emerging exporters, Colombia and Mexico are the ones with the highest correlation with the commodity price index (the coefficient of correlation is 0.84 and 0.89, respectively). In the case of the advanced commodity exporters, Canada and Norway are the ones more correlated with the IMF index (the coefficient of correlation is 0.91 for Canada, and 0.80 for Norway). One thing to highlight is that all the countries which have been mentioned export mainly some kind of energy commodity. For example, energy represents

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64% of Colombia's exports, 41% of Canada's, and 80% of Norway's[14]. Precisely, energy is the component with the highest participation in the IMF commodity price (around 41%), so the strong correlation with the terms of trade of the energy commodity exporters reflects in part the high weight given to coal, oil and gas in the computation of the IMF commodity price index.

To finish this section, Table 1 and 2 present for each country a series of statistics regarding volatility and correlation with commodity prices, as well as averages for each of the groups. The results are in line with the ones found by Shousha (2016). I find that, with the exception of the current account, all variables are more volatile in emerging than in advanced economies[15]. In terms of co-movement with commodity prices, emerging countries' output is more correlated. Moreover, as the literature review suggests, country interest rate has a negative correlation with commodity prices in emerging economies and a positive correlation in advanced economies. Finally, in line with the Figure 3, terms of trade are more correlated with the commodity price index in advanced economies since energy products are more relevant for these countries, while emerging economies exports are, on average, more concentrated on metals and agricultural products. However, terms of trade are much more volatile in emerging economies. This difference in terms of trade volatility can be an important source of heterogeneity in business cycle fluctuation between emerging and advanced economies. However, in the present work I do not not model this feature, although there are some papers which have try to exploit this source of variability (Bleaney and Greenaway, 2001; Blattman et al., 2007; Williamson, 2008; Andrews and Rees, 2009; and Gómez-Gonzáles and Rees, 2013).

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[14]In particular, in Colombia we have that crude oil accounts for 45% and coal for 19%; in Canada crude oil 25% and natural gas 16%, and in Norway crude oil 59% and natural gas 21%. For more details, see Table I of Shousha (2016).

[15]Shousha (2016) works with the trade balance-to-gdp ratio instead of the current account-to-gdp ratio, and finds that the trade balance is more volatile for emerging economies. However. I have decided to work with the current account because this variable gives a broader and more complete idea on the impact of commodity prices on countrys external balance. This is relevant, for example, for countries like Peru, where almost all commodity exporting companies are foreign owned. Therefore, as commodity prices increases so the profits of these firms. Since they are foreign owned, this increase in utilities is reflected in the investment income account of the balance of payments. Therefore, offsetting in part the positive effect of higher exports in the trade balance. This can be seen in Table 1, where Peru's current account shows a low correlation with commodity prices.

Table 1: Business Cycles Statistics - Emerging Economies

Statistic	Brazil	Chile	Colombia	Mexico	Peru	South Africa	All
Standard Deviations							
GDP	0.03	0.03	0.03	0.03	0.03	0.02	0.03
Inflation	0.03	0.02	0.06	0.08	0.03	0.03	0.04
Exchange Rate	0.21	0.11	0.15	0.10	0.07	0.17	0.13
Current Account	2.2%	3.7%	2.0%	1.0%	2.9%	2.2%	2.3%
Interest Rate	0.05	0.02	0.09	0.09	0.06	0.04	0.06
Terms of Trade	0.07	0.35	0.13	0.07	0.11	0.05	0.13
Corr. Commodity Price							
GDP	0.71	0.50	0.37	0.40	0.53	0.66	0.53
Exchange Rate	-0.56	-0.70	-0.57	-0.65	-0.56	-0.53	-0.59
Current Account	0.32	0.26	0.45	0.42	0.28	-0.02	0.28
Interest Rate	0.16	-0.14	-0.17	-0.10	-0.14	-0.11	-0.08
Terms of Trade	0.49	0.64	0.84	0.89	0.45	0.09	0.57

Note: The last column is the simple average of each indicator for the whole sample of countries. The data are sampled quarterly from 1996:Q1-2016:Q4. GDP and Inflation are computed as the year-to-year growth of the real domestic product and consumer price index, respectively. The variables Exchange Rate and Terms of Trade also corresponds to annual growth rates. The variable Current Account is computed as a percentage of GDP.

Table 2: Business Cycles Statistics - Advanced Economies

Statistic	Australia	Canada	New Zealand	Norway	All
Standard Deviations					
GDP	0.01	0.02	0.02	0.02	0.02
Inflation	0.01	0.01	0.01	0.01	0.01
Exchange Rate	0.13	0.08	0.14	0.12	0.12
Current Account	1.5%	2.3%	1.9%	4.4%	2.5%
Interest Rate	0.01	0.02	0.02	0.03	0.02
Terms of Trade	0.09	0.05	0.07	0.16	0.09
Corr. Commodity Price					
GDP	0.03	0.40	0.29	0.13	0.21
Exchange Rate	-0.68	-0.81	-0.57	-0.69	-0.69
Current Account	-0.32	0.41	-0.23	0.46	0.08
Interest Rate	0.54	0.18	0.44	0.12	0.32
Terms of Trade	0.62	0.91	0.40	0.80	0.68

Note: The last column is the simple average of each indicator for the whole sample of countries. The data are sampled quarterly from 1996:Q1-2016:Q4. GDP and Inflation are computed as the year-to-year growth of the real domestic product and consumer price index, respectively. The variables Exchange Rate and Terms of Trade also corresponds to annual growth rates. The variable Current Account is computed as a percentage of GDP.

3 The Multi-Country Panel VAR model

This section closely follows Canova and Ciccarelli (2009). I specify a Multi-Country model which features lagged inter-dependencies and time varying parameters. I abstract from the possible presence of Stochastic Volatility, since the current setup is already computationally demanding[16].

3.1 The setup

The statistical model employed in this paper has the form:

$$y_{it} = D_{it}(L) Y_{t-1} + F_{it}(L) Z_t + c_{it} + e_{it} \tag{1}$$

where $i = 1, \ldots, N$ refers to countries and $t = 1, \ldots, T$ refers to time periods. In addition, y_{it} is a $M \times 1$ vector of endogenous variables for each country i and $Y_t = (y'_{1t}, y'_{2t}, \ldots, y'_{Nt})'$.

I define the polynomials

$$D_{it}(L) = D_{it,1} + D_{it,2}L + \cdots + D_{it,p}L^{p-1}$$

$$F_{it}(L) = F_{it,0} + F_{it,1}L + \cdots + F_{it,q}L^q$$

where $D_{it,j}$ are $M \times NM$ matrices for each lag $j = 1, \ldots, p$. Moreover, Z_t is a $M_2 \times 1$ vector of exogenous variables common to all countries and $F_{it,j}$ are $M \times M_2$ matrices for each lag $j = 0, \ldots, q$, c_{it} is a $M \times 1$ vector of intercepts and e_{it} is a $M \times 1$ vector of random disturbances.

Notice that cross-unit lagged inter-dependencies are allowed whenever the $NM \times NM$ matrix $D_t(L) = [D_{1t}(L), D_{2t}(L), \ldots, D_{Nt}(L)]'$ is not block diagonal. Notice also that coefficients in (1) are allowed to vary over time and that dynamic relationships are unit-specific. All these features add realism to the econometric model. However, this comes at the cost of having an extremely large number of parameters to estimate (we have $k = NMp + M_2(1+q) + 1$ parameters per equation). For that reason, I specify a more parsimonious representation of the latter model

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[16]See also Canova et al. (2007), Canova and Ciccarelli (2012) and Canova et al. (2012).

in order to proceed to the estimation.

Equation (1) can be rewritten in a compact form as

$$Y_t = W_t \delta_t + E_t, \quad E_t \sim N(0, \Omega) \tag{2}$$

where $W_t = I_{NM} \otimes X_t'$; $X_t' = \left(Y_{t-1}', Y_{t-2}', \ldots, Y_{t-p}', Z_t', Z_{t-1}', \ldots, Z_{t-q}', 1 \right)$; $\delta_t = \left(\delta_{1,t}', \delta_{2,t}', \ldots, \delta_{N,t}' \right)'$ and δ_{it} are $Mk \times 1$ vectors containing, stacked, the M rows of matrix D_{it} and F_{it}, while Y_t and E_t are $NM \times 1$ vectors. Notice that since δ_t varies with cross-sectional units in different time periods, it is impossible to estimate it using classical methods. Even in the case of constant co-efficients, the amount of degrees of freedom needed to conduct proper inference is tremendously large. For that reason, Canova and Ciccarelli (2009) suggest to reduce the dimensionality of this problem as follows:

$$\delta_t = \Xi_1 \theta_{1t} + \Xi_2 \theta_{2t} + \Xi_3 \theta_{3t} + \Xi_4 \theta_{4t} + u_t \tag{3}$$

where $\Xi_1, \Xi_2, \Xi_3, \Xi_4$ are matrices of dimensions $NMk \times 1$, $NMk \times N$, $NMk \times M$, $NMk \times 1$ respectively. θ_{1t} captures movements in coefficients that are common across countries and variables; θ_{2t} captures movements in coefficients which are common across countries; θ_{3t} captures movements in coefficients which are common across variables; θ_{4t} captures movements in coefficients which are common across exogenous variables. Finally, u_t captures all the un-modeled features of the coefficient vector[17].

The factorization (3) significantly reduces the number of parameters to be estimated. In other words, it transforms an over-parametrized Panel VAR into a parsimonious SUR model, where the regressors are averages of certain right-hand side variables. In fact, substituting (3) in (2) I have

$$Y_t = \sum_{i=1}^{4} \mathcal{W}_{it} \theta_{it} + \upsilon_t$$

where $\mathcal{W}_{it} = W_t \Xi_i$ capture respectively, common, country-specific, variable-specific and exogenous-specific information present in the data, and $\upsilon_t = E_t + W_t u_t$.

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[17]See details in Canova and Ciccarelli (2009).

To complete the model, I specify $\theta_t = [\theta'_{1t}, \theta'_{2t}, \theta'_{3t}, \theta'_{4t}]'$ so that I have the law of motion:

$$\theta_t = \theta_{t-1} + \eta_t, \qquad \eta_t \sim N\left(0, B_t\right)$$

where B_t is block-diagonal with:

$$B_t = \gamma_1 B_{t-1} + \gamma_2 \overline{B}$$

where γ_1 and γ_2 are scalars and a $\overline{B}$ is block-diagonal matrix.

To summarize, the empirical model has the state-space form:

$$Y_t = \left(W_t \Xi\right)\theta_t + \upsilon_t \tag{4}$$

$$\theta_t = \theta_{t-1} + \eta_t \tag{5}$$

where $\upsilon_t \sim N\left(0, \sigma_t\right)$; $\sigma_t = \left(1 + \sigma^2 X'_t X_t\right)$ and $\eta_t \sim N\left(0, B_t\right)$. To compute the posterior distributions, I need prior densities for the parameters $\left(\Omega, \sigma^2, \overline{B}, \theta_0\right)$.

3.2   Priors

Following the references I set conjugated priors, i.e. such that the posterior distribution has the same shape as the likelihood function. In particular, given the normality assumption for the shocks, the variance and covariance parameters have an Inverse Gamma distribution or Inverse Wishart distribution for the multivariate case (see Zellner, 1971 and Koop, 2003). In addition, since I am going to use the Kalman filter and smoother for simulating the posterior distribution of latent factors, it is reasonable to assume the initial point as normally distributed.

$$p\left(\Omega^{-1}\right) = Wi\left(z_1, Q_1\right)$$

$$p\left(\sigma^2\right) = IG\left(\frac{\zeta}{2}, \frac{\zeta s^2}{2}\right)$$

$$p\left(b_i\right) = IG\left(\frac{\varpi_0}{2}, \frac{\delta_0}{2}\right), \qquad i = 1, \ldots, 4$$

$$p\left(\theta_0\right) = N\left(\overline{\theta}_0, \overline{R}_0\right)$$

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where the latter implies a prior for $\theta_t = N\left(\theta_{t-1|t-1}, R_{t-1|t-1} + B_t\right)$.

3.3 Posterior Distribution

The posterior distribution of model parameters is the efficient combination of prior information with the observed data. Denote the parameter vector as

$$\psi = \left(\Omega^{-1}, \{b_i\}_{i=1}^4, \sigma^2, \{\theta_t\}_{t=1}^T\right) \tag{6}$$

Given the normality assumption of the error term υ_t, the likelihood function of the Multi-Country Panel VAR model (4) is equal to

$$L\left(Y^T \mid \psi\right) \propto \left(\prod_{t=1}^T \sigma_t^{-NM/2}\right) |\Omega|^{-T/2} \exp\left[-\frac{1}{2}\sum_{t=1}^T \left(Y_t - W_t\Xi\theta_t\right)\left(\sigma_t\Omega\right)^{-1}\left(Y_t - W_t\Xi\theta_t\right)'\right] \tag{7}$$

where $Y^T = (Y_1, Y_2, \ldots, Y_T)$ denotes the data, and $\sigma_t = \left(1 + \sigma^2 X_t'X_t\right)$.

Using the Bayes' rule, I have the posterior distribution

$$p\left(\psi \mid Y^T\right) \propto L\left(Y^T \mid \psi\right) p\left(\psi\right) \tag{8}$$

In the next section I will explain how to obtain the optimal estimates of model parameters in a tractable way. So far, I have identified my object of interest, and the next step is to proceed to the estimation.

4 Bayesian Estimation

4.1 A Gibbs Sampling routine

Analytical computation of the posterior distribution (8) is impossible. However, I can factorize $p\left(\psi \mid Y^T\right)$ into different parameter blocks according to (6). The latter allows me to specify the following cycle:

1. Simulate $\{\theta_t\}_{t=1}^T$ from $p\left(\theta_t \mid Y^T, \psi_{-\theta_t}\right)$ such that

$$\theta_t \mid Y^T, \psi_{-\theta_t} \sim N\left(\bar{\theta}_{t|T}, \overline{R}_{t|T}\right), \ t \leq T \tag{9}$$

2. Simulate Ω^{-1} from $p\left(\Omega^{-1} \mid Y^T, \psi_{-\Omega}\right)$ such that

$$\Omega^{-1} \mid Y^T, \psi_{-\Omega} \sim Wi\left(z_1 + T, \left[\frac{\sum_t \left(Y_t - W_t \Xi \theta_t\right)\left(Y_t - W_t \Xi \theta_t\right)'}{\sigma_t} + Q_1^{-1}\right]^{-1}\right) \tag{10}$$

3. Simulate b_i from $p\left(b_i \mid Y^T, \psi_{-b_i}\right)$ such that

$$b_i \mid Y^T, \psi_{-b_i} \sim IG\left(\frac{\varpi^i}{2}, \frac{\sum_t \left(\theta_t^i - \theta_{t-1}^i\right)'\left(\theta_t^i - \theta_{t-1}^i\right) + \delta_0}{2\xi_t}\right) \tag{11}$$

where $\xi_t = \gamma_1^t + \gamma_2 \frac{1 - \gamma_1^t}{1 - \gamma_1}$.

4. Simulate σ^2 from $p\left(\sigma^2 \mid Y^T, \psi_{-\sigma^2}\right)$ such that

$$\sigma^2 \mid Y^T, \psi_{-\sigma^2} \propto L\left(Y^T \mid \psi\right) p\left(\sigma^2\right) \tag{12}$$

where $\bar{\theta}_{t|T}$ and $\overline{R}_{t|T}$ are the one-period ahead forecasts of θ_t and the variance-covariance matrix of the forecast error, respectively, calculated through the Kalman smoother, as described in Chib and Greenberg (1995). I also have $\varpi^1 = T + \varpi_0$, $\varpi^2 = TM + \varpi_0$, $\varpi^3 = TN + \varpi_0$, and $\varpi^4 = T + \varpi_0$.

The posterior of σ^2 is simulated using a Random-Walk Metropolis-Hastings step, since it is non-standard. That is, at each iteration l I draw a candidate $\left(\sigma^2\right)^*$ according to

$$\left(\sigma^2\right)^* = \exp\left[\ln\left(\sigma^2\right)^{l-1} + c_\sigma \varepsilon\right]$$

with $\varepsilon \sim N\left(0, 1\right)$ and c_σ is a parameter for scaling the variance of the proposal distribution. In particular, this is chosen such that the acceptance rate is between $0.2 - 0.4$. Moreover, the

acceptance probability at each draw l is given by:

$$\alpha = \min \left\{ \frac{L\left(\left(\sigma^2\right)^*, \psi^l_{-\sigma^2} \mid Y^T\right) p\left(\left(\sigma^2\right)^*\right) \varrho\left(\left(\sigma^2\right)^{l-1} \mid \left(\sigma^2\right)^*\right)}{L\left(\left(\sigma^2\right)^{l-1}, \psi^l_{-\sigma^2} \mid Y^T\right) p\left(\left(\sigma^2\right)^{l-1}\right) \varrho\left(\left(\sigma^2\right)^* \mid \left(\sigma^2\right)^{l-1}\right)}, 1 \right\}$$

where I take into account the fact that the proposal distribution is not symmetric.

Under regularity conditions, cycling through the conditional distributions $(9) - (10) - (11) - (12)$ will produce draws from the limiting ergodic distribution.

4.2   Estimation setup

I run the presented Gibbs sampler for $K = 150,000$ draws and discard the first $100,000$ in order to minimize the effect of initial values. Moreover, in order to reduce the serial correlation across draws, I set a thinning factor of 10, i.e. given the remaining $50,000$ draws, I take 1 every 10 and discard the remaining ones. As a result, I have $5,000$ draws for conducting inference. Priors are calibrated using a training sample based on the first five years of data. I set $\varpi_0 = 10^6$, $\delta_0 = 1$, $z_1 = NM + 5$, $Q_1 = diag\left(Q_{11}, \ldots, Q_{1N}\right)$ where Q_{1i} is the residual covariance matrix of the time invariant VAR for the i-th country, $\zeta = 1$, $s^2 = \hat{\sigma}^2$ where $\hat{\sigma}^2$ is the average of the estimated variances of NM independent $AR(p)$ models. Moreover, $\overline{\theta}_0 = \hat{\theta}_0$ is the OLS estimation of the time-invariant version of the model and $\overline{R}_0 = I_{dim(\theta_t)}$. Given the calibrated value of c_σ, the acceptance rate of the metropolis-step is around 0.38. Finally, I set $\gamma_1 = 0$ and $\gamma_2 = 1$, meaning that η_t has a constant variance.

4.3   Impulse responses computation

In this section I explain how to compute the dynamic responses at different points in time using the presented model. I define the Impulse Responses (IR) as follows: let the expression

$$IR_Y^j(t, h) = E\left(Y_{t+h} \mid F_t^1\right) - E\left(Y_{t+h} \mid F_t^2\right), \quad h = 1, 2, \ldots$$

be the response of vector Y_t to a shock in variable j of size δ at date t. Where

$$F_t^1 = \left\{ Y^t, \theta_{t+1}^{t+h}, S_t, J_t, \xi_{j,t}^\delta, \xi_{-j,t}, \xi_{t+1}^{t+h} \right\}$$

$$F_t^2 = \left\{ Y^t, \theta_{t+1}^{t+h}, S_t, J_t, \xi_t, \xi_{t+1}^{t+h} \right\}$$

$$S_t = (\Omega, B_t); \quad \Omega = J_t J_t'$$

and where

$$\theta_{t+1}^{t+h} = \left[\theta_{t+1}', \theta_{t+2}', \ldots, \theta_{t+h}' \right]'$$

$$Y_{t+1}^{t+h} = \left[Y_{t+1}', Y_{t+2}', \ldots, Y_{t+h}' \right]'$$

In order to forecast Y_{t+h} and θ_{t+h}, I use the equations (4) and (5), respectively. I repeat this procedure for a subset of random draws from the posterior distribution, and for different dates. Then I collect the draws and compute the median value and relevant percentiles.

5 Results

5.1 Data and variables selection

For each country I use year-to-year growth rates of gross domestic product (GDP), consumer price index (CPI), current account (as percentage of GDP), and real exchange rate. As in Canova et al. (2012), I include domestic price indexes in order to control for variation in nominal variables. I also include for each country the domestic interbank rate. As exogenous variables, I include the annual growth rate of US's GDP and the growth rate of the IMF Commodity Price Index. All the variables are taken from each country's central bank web site. The growth rate of US's GDP is obtained from the FRED database of the St. Louis' Fed and the commodity price index from the IMF's Primary Commodity Price System. The sample of analysis covers the period 1996Q1-2016Q4. Following the references, data is demeaned and standardized.

5.2 Model Comparison

The baseline specification considers one lag for domestic and exogenous variables, i.e. $p = 1$ and $q = 1$. I also include a common component, a country-specific component, a variable-specific component and an exogenous component, i.e. the complete set up proposed. In this section I compare this baseline specification with alternative ones. To do so, I compute the Marginal Likelihood for each model. That is, I integrate out the posterior distribution across the parameter space, and see to what extent a given model is a good representation of the data, i.e. the model with a higher marginal likelihood will be the best one. The marginal likelihood for each model M_i is

$$f\left(Y^T \mid M_i\right) = \int L\left(\psi_j \mid Y^T, M_i\right) P\left(\psi_j \mid M_i\right) dj$$

Given the scales, it is better to compute the log-marginal likelihood $\ln f\left(Y^T \mid M_i\right)$, and this is estimated using a standard harmonic mean estimator.

Table 3: Log-Marginal Likelihood of Different models

Model	Description	$\ln f\left(Y^T \mid M_i\right)$
M_1	Baseline Model $(p = 1, q = 1)$	-4168.8
M_2	No Country Component	-4172.2
M_3	No Variable Component	-4232.5
M_4	Alternative model $(p = 2, q = 2)$	-4561.6
M_5	Alternative model $(p = 2, q = 1)$	-4400.2

As it can be seen in Table 3, the baseline specification is good enough to capture all the dynamic interdependencies that are present in the data, since it is the option with the best log-marginal likelihood.

5.3 Analysis of commodity exporters GDP

The methodology used allows me to construct a common indicator for the whole sample of countries for a particular variable present in the model. This indicator, following Canova et al. (2012), corresponds to the posterior distribution of $\mathcal{W}_{3t}$ multiplied by the corresponding estimated θ_{3t}. Figure 4 presents the common indicator for the GDP variable, with 68% confidence bands.

Figure 4: Posterior distribution of the GDP Indicator
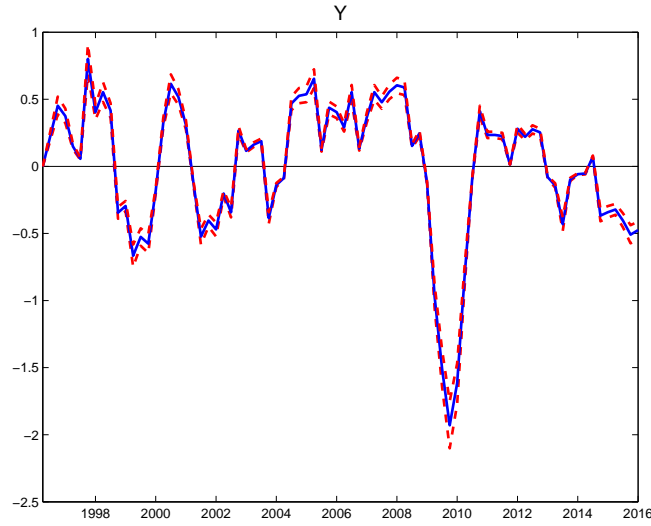
The previous indicator shows the average ups and downs of GDP growth and it is significant for the whole sample given the confidence bands. In particular, it captures the recession of 2008 and the decline in GDP growth experienced by most small open economies in 1998 due to the Russian financial crisis. The indicator also gives us the first evidence of the relation between GDP growth and commodity prices. For example, between 2000 and 2008 we see an important positive growth which coincides with one of high increase in the commodity price index (commodity prices increased 106.6 %). After 2008, commodity prices experienced a sharp decline, which can also be reflected in the previous indicator. Thus, this indicator reveals evidence of positive synchronization between GDP growth and commodity prices.

5.4 The transmission of commodity price shocks: A comparison between emerging and advanced countries

The previous section showed evidence of the positive relationship between commodity prices and GDP growth for commodity exporters. This section develops in detail the transmission mechanism of commodity price shocks. As in Shousha (2016), I make a distinction between emerging and advanced countries so I can study the heterogeneity effects of these shocks. The response of output, inflation, current account balance, and exchange rate after a positive commodity price shock (i.e. an increase in the commodity price index) is depicted in Figure 5.

Figure 5: Impulse Response Functions to a unit shock on Commodity Prices
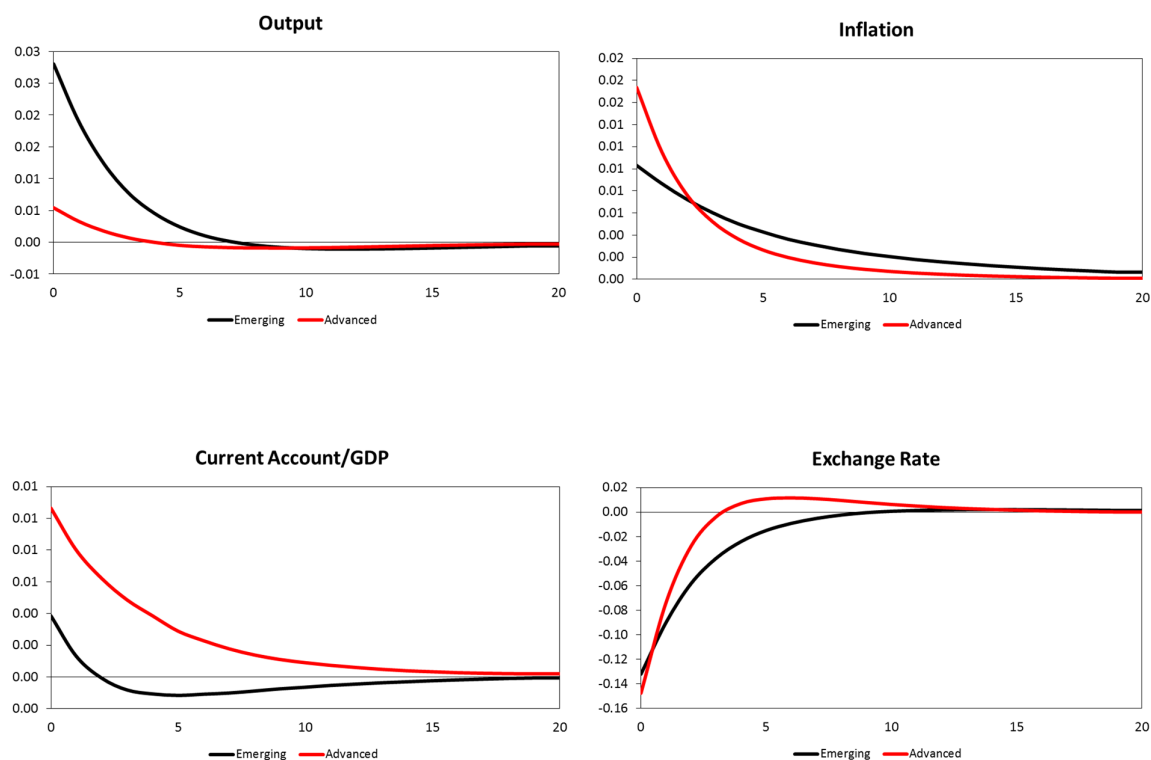
Note: Impulse Responses are computed following the procedure describe in section 4.3. For each horizon (from 0 to 20), the graphs show the simple average of the individual responses of each variable across countries.

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My results are in line with Shousha (2016). As expected, after an increase in commodity prices, there is a currency appreciation for both emerging and advanced economies. According to Chen and Rogoff (2003) and Cashin et al. (2004), the improvement in commodity prices produces an increase in the wage paid in the commodity sector and, assuming labor is mobile, this wage increase goes across the economy. This, in turn, pushes up the price of non-tradables. Since the price of tradables is exogenously determined in the world market, we get a relative increase in the price of non-tradables with respect to tradables. Thus, a real exchange rate appreciation. Following Schmitt-Grohé and Uribe (2018), this currency appreciation can be understood in terms of substitution and income effects. For one side, imports and non-traded absorption become relative cheaper. Therefore, the price of non-tradables increases as the economy demands more of those goods (substitution effect). On the other side, we get a positive income shock (income effect) because the price of the goods sold abroad are higher (countries receive more income for each good exported). This positive income shock pushes up the demand for all goods in the economy, including non-tradables. So, the relative price of non-tradables increases as a result of both effects. Although we do not see, on impact, much heterogeneity in the response between the two groups of economies, the effect on the exchange rate is quite more persistence for emerging economies.

The currency appreciation is also consistent with the observed improvement in the current account, mainly as a consequence of higher exports. Nonetheless, it is important to recall that the improvement in commodity prices also produces an increase in imports. As it was pointed out in the previous paragraph, the economy increases its demand for imports because, relative to exports, they have became cheaper (substitution effect). Therefore, the net effect on the current account depends on whether the response of exports to changes in commodity prices is higher or lower compared with the response of imports. According to Figure 5, the current account improves after an increase in the commodity price (i.e. there is a stronger response of export to commodity prices than imports). Therefore, I find significant evidence supporting the existence of a Harberger-Laursen-Metzler (HLM) effect[18]. Unlike the response observed for the exchange

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[18]Strictly, the HLM effect is related to the response of the trade balance. In general, the current account follows the pattern of the trade balance. However, in the next section we will see that this effect is only valid on average, because there are some countries that experience a deterioration of their current account balances after

rate, we do see a quantitative difference in the response of current account balances. According to my results, the current account in emerging economies experiences a lower improvement after an increase in commodity prices. This, as we will see in the next section, is associated with the profit repatriation carried out by foreign-owned commodity exporting firms in emerging economies.

In terms of output, we see that the improvement in commodity price causes an expansion in aggregate activity, and this effect is higher for emerging economies. The increase in output is consistent with the idea of commodity price shocks as income shocks. Additionally, the expansion in aggregate output should reflect the increased activity in the export and non-traded sector (Schmitt-Grohé and Uribe, 2018). Finally, the higher output growth drives up prices in the economy and produces inflationary pressures. However, currency appreciation works in the opposite direction since it pushes inflation down. My results suggest that the effect of higher demand dominates the one associated with currency appreciation.

5.5 The transmission of commodity price shocks: A comparison across countries

In this section I present an individual analysis of the responses of output, inflation, current account and exchange rate within each country group. This analysis is important because it allows to identify heterogeneity, which is one of the advantages of the empirical Panel VAR model used in this work.

I will begin the analysis with the emerging economies. We see that Colombia's and Mexico's current account experience the highest impact. This response is logical given that both countries are highly concentrated in the exports of energy products, which is the item with the highest participation on the IMF commodity price index. However, we see differences regarding the sign of the impact on the current account for some countries. In particular, the HLM effect does not apply for Peru and South Africa. The case of Peru is particular interesting because this response reflects the dual effect that commodity prices have on economies with a high share of foreign-owned commodity firms. The first effect is related with a pure HLM effect for

a positive commodity price shock.

the trade balance. After an increase in commodity prices, as we stated, exports respond more than imports; thus producing an improvement in the trade balance. Although my empirical model does not take into account explicitly the trade balance, there is evidence this effect is present for Peru (for example, Schmitt-Grohé and Uribe (2018) find that a 10% increase in the terms of trade causes an improvement in Peru's trade balance of 1.5 percent of GDP). The second effect works through profit repatriation, which becomes relevant when a country has commodity exporting firms mostly owned by non-residents. In the case of Peru, commodity exports are mainly concentrated in metal products (copper, gold and zinc). Additionally, this mining companies are private and owned by non-residents. Therefore, the increase in commodity price produces immediately a positive effect on commodity firms' profit. Since they are owned by non-residents, this increase is reflected as profit repatriations in the current account balance. Depending on the magnitude of both effects, the current account can improve or deteriorate after a positive commodity price shock. According to my results, profit repatriations more than offset the positive impacts on trade balance (similar results are found by Tashu, 2015). This is in line with the high participation of profit repatriation on Peru's current account: between 1996 and 2016, profit repatriation amounted on average to about 3.9 percent of GDP a year, while trade balance represented on average only 1.8 percent of GDP a year. This explains why for most of my sample period, Peru has run current account deficits.

In terms of the response of the exchange rate, we see differences on the quantitative impact but not in sign. Moreover, the exchange rate response is aligned on average with the degree of exchange rate flexibility of these countries. For instance, Brazil is the country with highest exchange rate volatility among emerging economies (see Table 1); thus its currency is the one which responds stronger after a commodity price shock. On the other hand, the response of Peru's exchange rate is the lowest because it is the country with the most stable currency (see Table 1). This last effect is also present in the work of Tashu (2015) and it is associated with an active forex (FX) intervention by Peru's central bank. This intervention seeks to limit the risks associated with exchange rate volatility within a context of financial dollarization. The logic behind the limited impact on the exchange rate after a commodity price shock works as follows. After a positive commodity price shock we see on average an inflationary pressure (see

Figure 5). Under an inflation targeting framework, like the one present in Peru and in most of the emerging economies of my sample, the central bank offsets this inflation pressure by increasing its policy interest rate. However, this causes an increase in capital inflows, which should appreciate further the exchange rate. If the central bank intervenes in the FX market, through the purchase of foreign currency; then its higher demand for foreign currency absorbs the effects of capital inflows. As a consequence, FX intervention limits the impact of capital inflows on the exchange rate, and makes this last variable less sensitive to changes in commodity prices. Finally, one last comment can be said about the response of Chile's exchange rate. We see that on impact, Chile's exchange rate appreciates. However, as time passes, we observe a currency depreciation. Using data post-1999 (the time Chile adopted the inflation targeting full flexible-exchange-rate regime), DeGregorio and Labbé (2011) reach a similar conclusion. According to the authors, this pattern is consistent with a flexible exchange rate regime, where foreign shocks are absorbed by the nominal exchange rate. Regarding the dynamics of output, we see similar patterns among emerging economies. The highest impact is recorded for Brazil, while the other economies present quantitative similar impacts and degrees of persistence. The impact on inflation presents more heterogeneity. All countries, except Mexico, show an increase in inflation after the commodity price shock. In Mexico we see a decrease, which means that the effect of the exchange rate appreciation in Mexico is stronger than the induced expansion in demand (note that Mexico has the second largest currency appreciation). For all the other emerging exporters, the increase in prices due to the expansion in output more than offsets the decrease in prices generated by the exchange rate appreciation.

Within advanced economies we see less heterogeneity in the responses. For instance, the responses of exchange rate and inflation are quite similar among Australia, Canada, Norway, and New Zealand. The main difference appears in the response of the current account and output. For example, Australia's output decreases after an increase in the commodity price, while we observe output growths in Canada, Norway and New Zealand. In terms of the response of the current account, I find no evidence of a HLM effect in New Zealand and Australia, while the highest impact is recorded for Norway, a country mainly concentrated in the exports of energy products.

Figure 6: Emerging Economies - Impulse Response Functions
to a unit shock on Commodity Prices
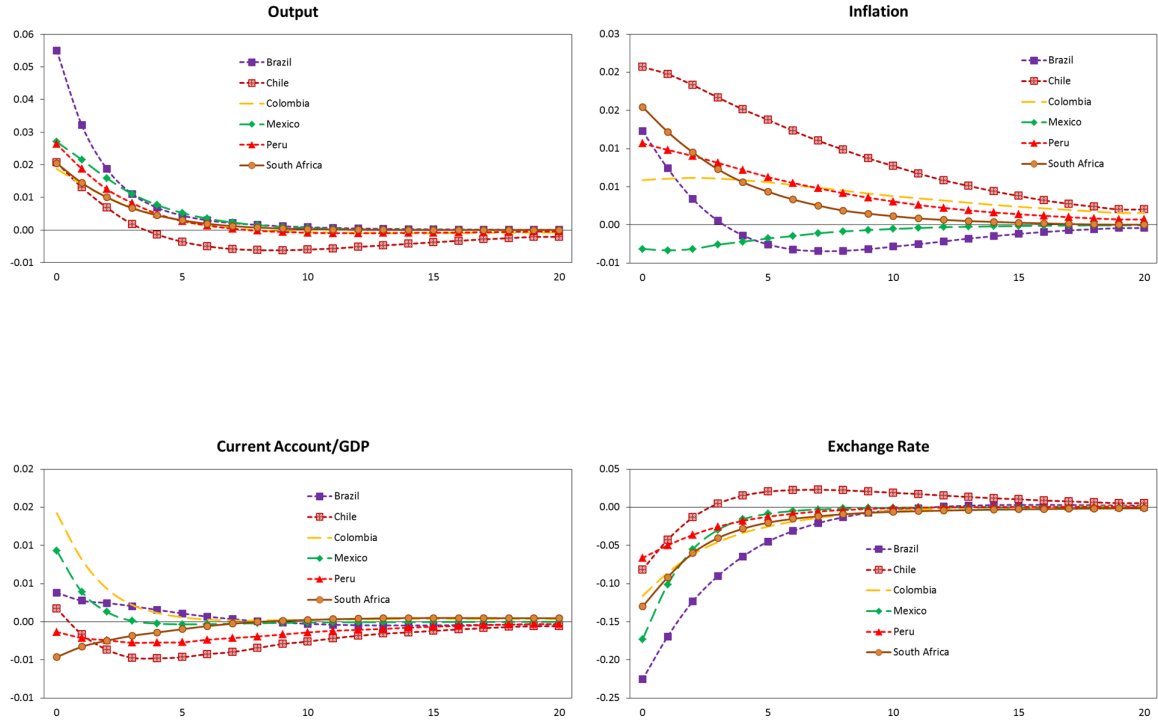
Note: Impulse Responses are computed following the procedure describe in section 4.3. For each horizon (from 0 to 20) and country, the graphs show the simple average responses of each variable.

Figure 7: Advanced Economies - Impulse Response Functions
to a unit shock on Commodity Prices
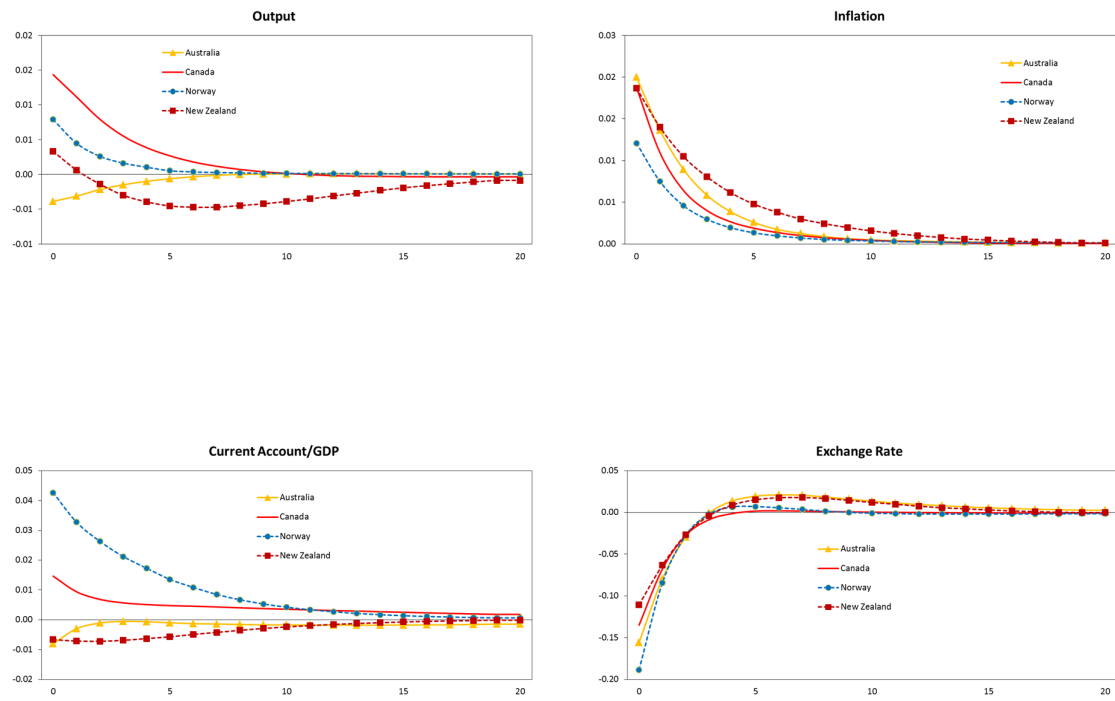
Note: Impulse Responses are computed following the procedure describe in section 4.3. For each
horizon (from 0 to 20) and country, the graphs show the simple average responses of each variable.

5.6 The transmission of commodity price shocks: A comparison across countries and time

The previous sections gave an overall picture of the impacts of commodity price changes on output, inflation, exchange rates and the current account. In this section, I exploit the versatility of the methodology to see if there is heterogeneity in the responses across time. Therefore, I compute the impulse response functions for a unit shock so I can analyze the dynamic across countries and for different time periods, which is one of the most important outputs that it can be obtained through the Panel VAR methodology.

Figure 8: Response of GDP to a unit shock on Commodity Prices
(median value and 68% bands)

(a) 2002　　　　　　　　　　　　　　　　　　　(b) 2010
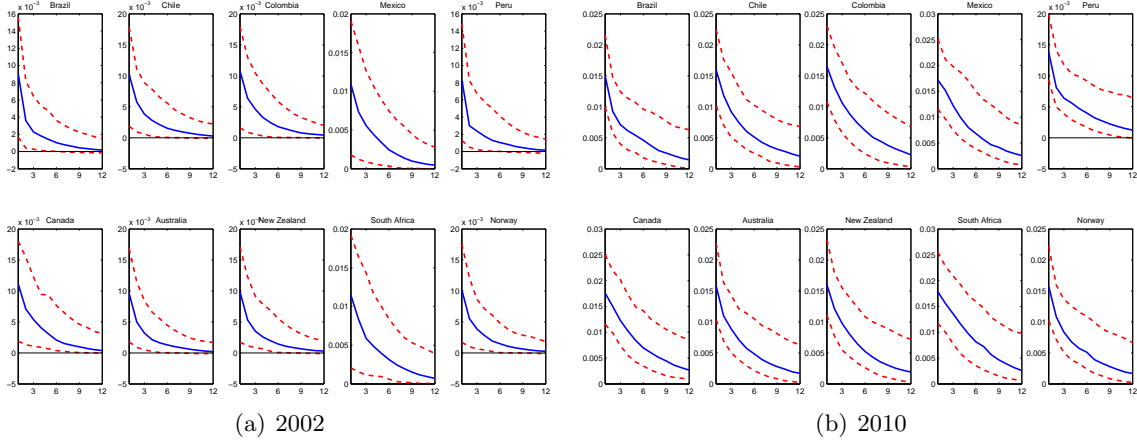
As we saw in Figures 6 and 7, there are on average positive impacts on output. Too see if this positive effect has changed across time, I compute for each country the dynamic impulse responses for GDP. The results are presented in Figure 8. In particular, I compute the impulse response assuming a commodity price shock in 2002 and 2010. As we can see, the dynamic response of GDP has changed along the sample. In fact, GDP patterns are qualitatively similar but there is heterogeneity in the magnitude of the responses. For all countries, commodity price shocks had, quantitatively, a stronger impact in 2010 compared to 2002. Thus, these shocks have become more important for commodity exporters.

6   Concluding Remarks

This paper has studied the effects of commodity prices for small open economies. To achieve that, I estimate a Panel VAR model with dynamic inter-dependencies and time varying parameters for a group of small emerging (Brazil, Chile, Colombia, Mexico, Peru, and South Africa) and advanced (Australia, Canada, New Zealand, and Norway) commodity exporters. I depart from the standard analysis by using a common commodity price index computed by the IMF. I show that this commodity index follows closely the swings of each country's terms of trade. The main contribution of my work is to employ this index within a Panel VAR model with inter-linkages among countries and time.

The previous framework allows me to make three lines of analysis. First, I find positive effects for output and inflation, as well as exchange rate appreciation and improvements in the current account. These effects are present on average for both emerging and advanced economies. The second line of analysis works at the country level. The individual responses tend to be similar with the ones found for group countries. However, there are important difference for some countries. For example, decreases in GDP for Australia, a reduction in inflation for Mexico and current accounts deterioration for Australia, New Zealand, Peru and South Africa. Finally, by computing impulse responses for different time periods, I find evidence that the impact of commodity prices on GDP has increased since 2002.

Future research agenda can be extended along two lines. Considering that commodities behave as any other asset in the economy, their variances are an important source of macroeconomic fluctuation for the economy. Therefore, the empirical model used in this paper can be extended to include explicitly commodity price volatility. Then, a model such as a Panel VAR with stochastic volatility can be an important tool. Finally, most of the theoretical models that study the impact of commodity prices on output rely on a distinction between traded and non-traded sector effects. However, most countries do not have disaggregated data at that level. The empirical model can be improved if such detailed data is constructed.

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