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Global shocks in emerging economies: An empirical investigation*

Mauro Sayar Ferreira[†]
André Cordeiro Valério[‡, §]

Contents

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Global shocks, business cycle, uncertainty, commodity price, sovereign risk, SVAR

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Abstract · Resumo

Shocks in commodity prices are viewed as a major driver of emerging economies' business cycle. We show this is not the case for Brazil, Chile, Colombia, and Peru when a structural vector autoregressive model accounts for macro-finance linkages at world and domestic levels. The presence of a global financial variable modifies established results as it endogenously influences commodity prices. Global demand shocks have been the main external driver of the business cycle in Brazil, Chile, and Peru, while global economic uncertainty shocks have been the main international driver of the Colombian GDP.

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†CEDEPLAR/UFMG. Av. Antonio Carlos, 6627, Belo Horizonte, Minas Gerais, CEP 31270-901, Brazil. 0000-0003-2865-2281

‡FGV EPGE. Praia de Botafogo, 190, 11th floor, Rio de Janeiro, Rio de Janeiro, CEP 22250-900, Brazil. 0000-0001-5073-6815

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mferreira@cedeplar.ufmg.br andre.valerio@fgv.edu.br

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1. Introduction

Despite the great interest in evaluating the impact of global shocks in small open economies, most works do not deal with the existent relationship between international variables. For instance, it is common to study the influence of a shift in commodity price without considering its drivers. This limits the understanding of the potential mechanisms through which domestic economies react to global shocks and affects the relevance attained by each of them in the determination of local business cycle.

We investigate how four emerging economies—Brazil, Chile, Colombia, and Peru—react to global shocks after considering a VAR structure with macro-finance linkages at the world level. Besides being from South America, all these countries adopt an inflation targeting regime and have their commodity sector playing important role in the determination of the trade balance.

Estimation and inference are conducted according to Bayesian structural VAR (BSVAR) with block recursion restrictions to impose the small open economy hypothesis, following Cushman and Zha (1997). The global bloc of the VAR uses three variables: a measure of world GDP, an aggregate commodity price index, and a financial volatility index (VIX). Five variables form the domestic bloc: sovereign spread (country risk), nominal exchange rate, GDP, consumer price index (CPI), and policy interest rate. The fact that these variables are present in several monetary DSGE models for small open economies facilitates comparisons.

Our identification strategy results in impulse responses one would expect from the following world shocks: demand, supply, and financial uncertainty. Under the complete macro-finance structure, world demand and world financial uncertainty shocks become more important determinants of domestic business cycles. Robustness analysis show that the absence of the VIX from the VAR inflates the relevance attained by commodity prices in the determination of domestic business cycles.

Related Literature

The necessity for analyzing commodity prices in a global general equilibrium environment has been pushed forward by Kilian (2009) in the context of the oil market, and by Alquist and Coibion (2014) and Charnavoki and Dolado (2014) for the aggregate commodity market. Alquist and Coibion (2014) verify that direct factors associated to commodity markets have played minor role in explaining price changes from 1969 to 2013, with general equilibrium effects contributing more intensively, particularly in periods of price booms as in the decade of 2000. Charnavoki and Dolado (2014), on the other hand, find that commodity specific shocks explain the largest fraction of the variation in their commodity price factor from 2000 to 2010, followed by global supply shocks. According to their results, global demand shock has played the smallest role.[1] Morana (2013), on the other hand, emphasizes the role played by financial uncertainty in the determination of oil prices, a relation not considered by Alquist and Coibion (2014) and Charnavoki and Dolado (2014).

More generally, the importance of finance uncertainty has been highlighted by Carrière-Swallow and Céspedes (2013), Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018), Christiano, Motto, and Rostagno (2014), Baker, Bloom, and Davis (2015), all reporting a fall in economic activity after a rise in measures of risk.[2]

The impact of world financial conditions in the business cycle of emerging economies has also been widely studied by several authors like Calvo, Leiderman, and Reinhart (1993), Mendoza (1991), Arora and Cerisola (2000), Neumeyer and Perri (2005), Uribe and Yue (2006), Shousha (2016), and Fernández, González, and Rodriguez (2018), to cite a few. Most papers try to capture international financial shock by sudden shifts in a measure of world interest rate. However, Akinci (2013) verifies a negligible influence of US real interest rate shocks to emerging markets activity after controlling for global financial risk, which he finds to explain about 20% of output oscillation in the emerging economies he studies. For this additional matter, we use a measure of world financial uncertainty as the relevant variable capable of capturing the state of global finance.[3]

Country specific risks are also another important source of local business cycle, especially sovereign risk that correlates negatively with local activity (Mendoza, 1991; Calvo et al., 1993; Arora & Cerisola, 2000; Uribe & Yue, 2006; Bocola, 2016). We confirm this relation even after controlling for various source of global shocks, but we also verify a large influence exerted by international shocks in accounting for the forecast error variance (FEV) of the sovereign risk, highlighting its role as a transmitter of global shocks as emphasized by Akinci (2013) and Fernández, Schmitt-Grohé, and Uribe (2017).

Despite of being related to several branches of the international macroeconomics literature, the work of Fernández et al. (2018) is our closest reference. They incorporate several of the previous features in a DSGE model for a commodity

[1] Charnavoki and Dolado (2014) study how Canada is impacted by innovations to global demand, global supply and shocks specific to the commodity market.

[2] Throughout the paper we will abuse and treat risk and uncertainty interchangeably. Bekaert, Hoerova, and Duca (2013) acknowledge this difference and decompose the Volatility Index (VIX) of the Chicago Board Options Exchange (CBOE) into uncertainty and risk, verifying that both produce similar impact on the US economy, affecting the monetary policy and being impacted by the economic cycle and policies.

[3] An additional advantage of not using a measure of world policy interest rate, like the Fed Funds rate, is to avoid issues related to the endogeneity of the monetary policy that tends to move in response to shocks elsewhere.

exporter emerging economy, which allows them to study the domestic effects of several global shocks. Despite their contribution, the model does not capture a full general equilibrium at world level, since the international financial variable is strongly exogenous to global activity and commodity prices, and vice-versa. To the extent that commodity prices actually react to innovations arising at the financial sector, their set up may reduce the importance attained by these innovations while increasing the relevance of shocks in the commodity market.

The rest of the paper is divided as follows. Section 2 presents methodological issues: the data used, the econometric model, and the restrictions imposed to recover structural shocks. In section 3 we present and analyze the results by studying the impulse response functions (IRFs) and forecast error variance decomposition (FEVD). In section 4 we conduct a discussion comparing the methodology we adopt, and the results obtained in the literature. Finally, section 5 concludes. In the appendix we present specific details regarding the Bayesian estimation procedure of Zha (1999), including the priors. We also show IRFs and FEVD of several alternative models and identification.

2. Empirical Strategy

2.1 Data

The VAR model uses quarterly data from the first quarter of 2000 through the second quarter of 2017 for Brazil, Chile, Colombia, and Peru. Being from the same region helps controlling for possible geographical effects. During this period the world economy faced important events, like the prominent role assumed by China which led to a commodity price boom, the 2008/2009 financial crisis that pushed the world to a big recession and provoked an immense fall in asset prices, among others.[4]

Our VAR structure includes an international and a domestic bloc. The international bloc contains three variables capable of capturing a macro-finance linkage: a measure of world GDP computed by the World Bank, the IMF all commodity price index, and the volatility index VIX.

The World Bank estimates the global GDP at current price using constant US dollar of 2010 based on information of all World Bank members. Our impulse responses show that this measure of global GDP responds to global shocks as one would expect from a GDP series. Similarly, innovation in this variable moves the

[4]According to Fernández et al. (2017) estimates, global shocks explain more than 60% of aggregate fluctuations in individual countries from 2003 to 2014, which is twice larger than when their sample ranges from 1960 to 2014.

others as one would expect from a global demand shock. The commodity price is the IMF *all commodity price index* that uses the US dollar as the reference currency. Since we are also interested in evaluating the effect of international shocks on nominal variables, we do not deflate the price index. Finally, the VIX is a stock market (S&P500) volatility index and has been widely used to capture worldwide economic uncertainty since Bloom (2009).

Our VAR system does not incorporate specific series of commodity prices that would matter exclusively to a unique country. For instance, we do not use the copper price when modelling the Chilean economy. This option has to do with our interest in situations where common aggregate global shocks matter for all commodity markets, causing their prices to co-move. Our sample period is one of intense co-movement in commodity prices of several sectors, affecting imports and exports in the same direction. Under such scenario, analysis strictly focused on the consequences of variation in the price of the relevant exporting commodity to a particular country may not be appropriate, since the net effect on the trade balance is not so obvious.[5]

The domestic variables were chosen to provide a better understanding of the channels through which structural shocks dissipate in a macro-finance setting. A risk adjusted interested parity (IP) is certainly one of the most important relations linking domestic and international finances. As such, we incorporate nominal exchange rates against the US dollar and the Emerging Market Bond Index Global (EMBIG), which is a measure of sovereign spread (country risk) computed by the investment bank JPMorgan Chase.[6] We also include the policy interest rate, which, despite of also entering in IP conditions, is the main monetary instrument in the inflation targeting regime of the countries we study. For the real sector, we use real gross domestic product (GDP) and the consumer price index (CPI). All variables enter in level after a logarithm transformation, except for the nominal interest rate that enters without any transformation.

2.2 The Econometric Methodology

The econometric model is a structural vector autorregression (SVAR) following the general form[7]

$$A_0 y_t = \sum_{\ell=1}^{p} A_\ell y_{t-\ell} + \varepsilon_t,$$

[5]See Chen and Rogoff (2003), Cashin, Céspedes, and Sahay (2004), Fernández et al. (2017), and Bianchi, Ilut, and Schneider (2018).

[6]Increases in the exchange rate are devaluations of the local currency against the US dollar.

[7]The exposition follows closely Waggoner and Zha (2003).

where y_t and ε_t are $n \times 1$ column vectors containing, respectively, n endogenous variables and and n structural disturbances.[8] Time is indexed by $t = 1, \dots, T$, and $\ell = 1, \dots, p$ is the lag length, which we set to $p = 4$, a standard practice when dealing with quarterly data. A_0 and A_ℓ are $n \times n$ matrices of coefficients, with A_0 informing the contemporaneous relations between the variables present in y_t. Each matrix A_ℓ contains the coefficients responsible for the dynamics of the model. The coefficients in each row $i = 12, \dots, n$ of matrices A_0 and A_ℓ are associated to the equation of the variable $y_{i,t}$ in the same row.

It is convenient to partition $y_{t-\ell}$ in two blocs so that $y_{t-\ell} = (y_{1,t-\ell}, y_{2,t-\ell})'$, where $y_{1,t-\ell}$ and $y_{2,t-\ell}$ are column vectors with dimensions $n_1 \times 1$ and $n_2 \times 1$, respectively, and $n = n_1 + n_2$. The vector ε_t and the matrix A_ℓ can also be partitioned to maintain coherence with $y_{t-\ell}$:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}, \qquad A_\ell = \begin{bmatrix} A_{11,\ell} & A_{12,\ell} \\ A_{21,\ell} & A_{22,\ell} \end{bmatrix}.$$

The dimensions of $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are, respectively, $n_1 \times 1$ and $n_2 \times 1$. Matrices $A_{11,\ell}$ and $A_{21,\ell}$ are both $n_1 \times n_1$, while $A_{12,\ell}$ and $A_{22,\ell}$ are $n_2 \times n_2$. We follow Sims and Zha (1998), Zha (1999), and Cushman and Zha (1997) and estimate the VAR using bayesian methods with priors suggested by Sims and Zha (1998). Specifically, we combine the Minnesota prior and the sum-of-coefficients prior.[9]

2.3 Lag restriction

It is reasonable to assume that small open emerging economies do not influence world aggregate economic variables. For this reason, we follow Cushman and Zha (1997) and impose bloc exogeneity to prevent domestic variables from affecting the recursion of any global variable.

The restriction is that $A_{12}(\ell) = 0$, so we assume $y_{1,t-\ell}$ to be the bloc containing international variables and $y_{2,t-\ell}$ being formed by domestic variables. The matrix A_ℓ becomes

$$A_\ell = \begin{bmatrix} A_{11,\ell} & 0 \\ A_{21,\ell} & A_{22,\ell} \end{bmatrix}.$$

Similar restriction is imposed in the equation for the sovereign spread, which we assume to be dynamically influenced by its own lags and by past and present values of the international variables. The reason for not allowing other domestic variables to explain the country risk, even with lags, has to do with our choice

[8] In our setup we do not explicitly consider the presence of exogenous variables, although the restriction on the lagged structure of the international variables guarantees complete exogeneity of these variables with respect to domestic ones.

[9] More details regarding the priors are in the Appendix B.

of not modeling expectations regarding fiscal sector variables, which restricts a proper modeling of the debt dynamics, the ultimate responsible for determining sovereign risks.[10] Furthermore, since sovereign spreads are strongly correlated to other domestic variables, especially with nominal exchange rate through a risk adjusted interest parity condition, allowing a feedback from this variable to country risk produces an erroneous causal adjustment of the sovereign risk that feeds back into the system.

2.4 Identification of the contemporaneous structural relations

Contemporaneous structural relations are captured by the coefficients in matrix A_0, where each row representing one equation. The system is organized in four blocs: an international bloc composed by world GDP, VIX and the commodity price index; a domestic international finance bloc containing the sovereign spread (country risk) and the nominal exchange rate; a domestic real sector bloc composed of GDP and CPI; and a policy bloc, solely composed by the domestic policy interest rate.

The benchmark structural identification of A_0 is based on the informational method proposed by Leeper, Sims, and Zha (1996). Accordingly, a variable contemporaneously reacts to a shock if its information content triggers an immediate response of the agents responsible for acting upon that specific variable to the point of disturbing it immediately.

Consistent with such strategy, all variables within a bloc must be allowed to respond contemporaneously to innovations in the same variable from another bloc. Based on this scheme, global variables do not respond to domestic variables. The domestic international finance bloc, given it is formed by high frequency forward looking variables, can move instantaneously to any news arriving from the international bloc. Regardless of observing the movements in these blocs, we consider that agents in charge of the real sector wait at least one period to adjust production and prices. Finally, the Central Bank board (or staff) continuously monitors domestic and international variables, which may all contemporaneously affect the determination of the policy interest rate, especially when looking at a quarterly frequency perspective.

Identification inside each bloc satisfies a standard Cholesky ordering. According to Zha (1999) this is a necessity to prevent losing the bloc structure during the estimation procedure, which could happen when the matrix is inverted. The impact

[10] Government debt and perspectives about international reserves are notably the most important domestic variables for the determination of emerging markets' sovereign risk. While the effect of shocks in the balance of payment can be captured by the state of the international variables, we do not incorporate variables that allow for a complete view of the state of the public finance. This means that our model lacks information about expectations on public debt, the ultimate responsible for determining country risks.

matrix A_0 is given by

$$A_0 = \begin{array}{r} \\ WGDP \\ VIX \\ PCOM \\ CR \\ EXR \\ GDP \\ CPI \\ INTR \end{array} \begin{array}{c} \begin{array}{cccccccc} \varepsilon_t^{\text{wdem}} & \varepsilon_t^{\text{wunc}} & \varepsilon_t^{\text{wsup}} & \varepsilon_t^{\text{cr}} & \varepsilon_t^{\text{fx}} & \varepsilon_t^{\text{dem}} & \varepsilon_t^{\text{sup}} & \varepsilon_t^{\text{mon}} \end{array} \\ \begin{bmatrix} a_{1,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{2,1} & a_{2,2} & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{3,1} & a_{3,2} & a_{3,3} & 0 & 0 & 0 & 0 & 0 \\ a_{4,1} & a_{4,2} & a_{4,3} & a_{4,4} & 0 & 0 & 0 & 0 \\ a_{5,1} & a_{5,2} & a_{5,3} & a_{5,4} & a_{5,5} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{6,6} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{7,6} & a_{7,7} & 0 \\ a_{8,1} & a_{8,2} & a_{8,3} & a_{8,4} & a_{8,5} & a_{8,6} & a_{8,7} & a_{8,8} \end{bmatrix} \end{array}.$$

While the recursive structure inside each domestic bloc is more standard, the same cannot be said about the international bloc. According to our benchmark identification, global GDP is only impacted contemporaneously by its own innovation, which we interpret as a global demand shock ($\varepsilon_t^{\text{wdem}}$) that also disturbs VIX and commodity prices on impact. But the ordering of the last two seems more controversial.

Our scheme assumes that commodity price index reacts contemporaneously to global financial uncertainty shocks, modeled as innovations in the VIX equation ($\varepsilon_t^{\text{wunc}}$). The commodity price index is the only global variable affected contemporaneously by innovations in the commodity market ($\varepsilon_t^{\text{wsup}}$). Given the financialization of the commodity market, our strategy still maintains a high frequency forward looking variables coming last. However, this would be equally satisfied if VIX came in last and the price index in second, not reacting instantaneously to uncertainty shocks. This option is verified and the impulse response functions, presented in the Appendix C, do not make economic sense if one is willing to interpret shocks as demand, uncertainty and supply. Specifically, an adverse shock to the commodity market (leftward move of the aggregate supply curve) results in a fall in volatility, a movement difficult to reconcile with theory and common-sense knowledge of responses in the financial market. Such a reaction would put in check the interpretation that a sudden and unexpected increase in commodity price index is an adverse supply shock, something that does not happen when VIX comes before price index in the impact matrix.

3. Results

We first report impulse response functions (IRF), and their 68% confidence intervals.[11] To facilitate comparisons, these innovations are normalized to guarantee that

[11] These probabilities bands were computed using the method developed by Sims and Zha (1999), to innovations in the equations of the global GDP, VIX, and commodity price.

the aggregate commodity price index increases by 10% on impact regardless of the shock.[12] Later we decompose the forecasting error variance (FEV) to estimate the contribution of each shock for the oscillation of each variable of our system.

3.1 Global shocks and the international economy

The IRFs in Figure 1 show the commodity price index increasing and the VIX falling after an unexpected rise in global GDP. An unexpected drop in VIX is followed by an increase in the world GDP and in the commodity price index, while an unexpected increase in the commodity price index drives volatility upwards and reduces the world GDP. Despite of not having specified a DSGE model, these are all the expected responses following a positive shock to global demand, a negative shock to uncertainty, and an adverse global supply shock.[13]

It is particularly interesting to distinguish the dynamics of commodity price following the positive shock in WGDP and the negative in VIX. They both generate larger WGDP, smaller volatility and, due to normalization, a 10% instantaneous drop in commodity price. The 0.85% positive demand shock necessary to produce a

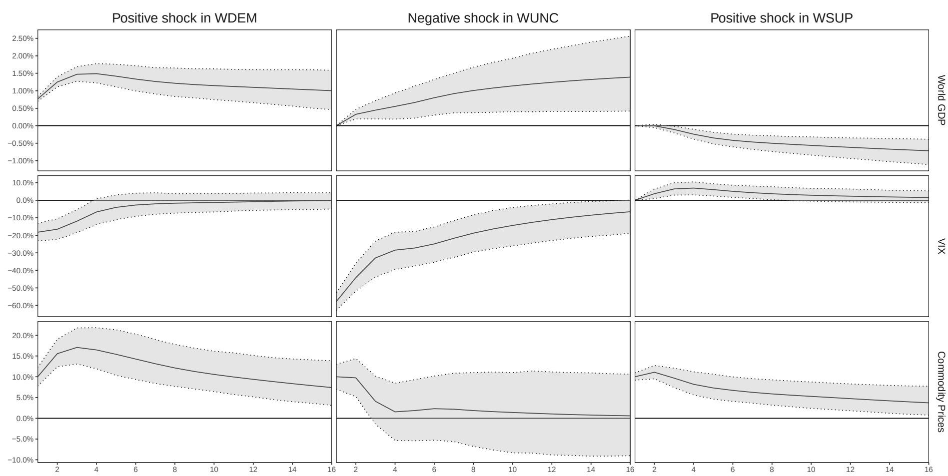

Figure 1. Impulse response functions of the international variables. WDEM, WUNC, and WSUP represent, respectively, world demand, world financial uncertainty, and world supply. Negative and positive are related to the direction of the shock, and not its quality. As such, a negative shock to WUNC refers to a shock that reduces world financial uncertainty, while a positive shock in WSUP refers to an adverse shock that moves the supply curve leftwards.The shadow areas indicate the 68% confidence interval.

[12]This is only possible in our preferred ordering scheme because the commodity price index comes last in the international bloc.

[13]A negative uncertainty shock has to do with the direction of the shock and should be interpreted as qualitative positive innovation that reduces the uncertainty.

10% rise in commodity price also results in a 17.5% drop in volatility. It is however required a 52% drop in volatility to produce an instantaneous 10% augment in the commodity price index, which starts falling right after the initial rise, moving towards pre-shock path in a much faster pace than the more persistent adjustment following the demand shock. These results suggest that the financial volatility elasticity of the aggregate commodity price differs substantially depending on the shock, being larger in the presence of a global demand shock.

In the presence of an unexpected rise in commodity price, global variables react as expected following an adverse supply shock: commodity price and volatility increase, while global GDP falls. These responses in price and activity are similar to what Charnavoki and Dolado (2014) report after a positive innovation to their commodity specific factor, which we believe to be capturing a world aggregate supply shock[14].

3.2 Global shocks and the national economies

3.2.1 Global activity shock

Figure 2 shows a common pattern to all countries following a positive shock in world activity, which we verified to produce global impacts one would expect after a demand shock. Country risks drop between 15% and 18% on impact, which is similar in magnitude to the fall in the VIX (17.5%). After the 2^{nd} quarter they start increasing, moving towards pre-shock level. The Chilean risk restores in 5 quarters, the fastest among the 4 countries.

Nominal exchange rates move as expected by risk adjusted interest rate parity: a drop in sovereign risk causes an immediate appreciation of domestic currencies. On impact, the Brazilian currency has the most intense gain (7%) and the Peruvian the smallest (2%). All currencies present high persistence that delays the return to regular path. This seems to be associated with similar persistence followed by the world GDP and the commodity price index, which would favor a lasting inflow of money to all four commodity exporters.

Domestic GDPs follow the world GDP and increase, but with different dynamics among the countries. The Chilean presents a humped shape pattern, reaching a peak of 1% excessive GDP in 5 quarters. The Brazilian and the Peruvian also increase until the 4^{th} or 5^{th} quarters, but do not return afterwards. The Colombian product reacts slower but maintains a steady rise in the following quarters.

Despite the inflation in commodities, the CPI responses are very heterogeneous. It significantly falls short of the regular path in Brazil, while a move in opposite

[14] Charnavoki and Dolado (2014) try to capture world supply shocks through innovations in a measure of world inflation. The responses of world activity and commodity prices following such shock have a similar pattern as that caused by an innovation in their commodity price factor. The difference occurs in the persistence of global activity, which is stronger following a shock in the level of the commodity price factor but less intense after an innovation in the measure of global inflation.

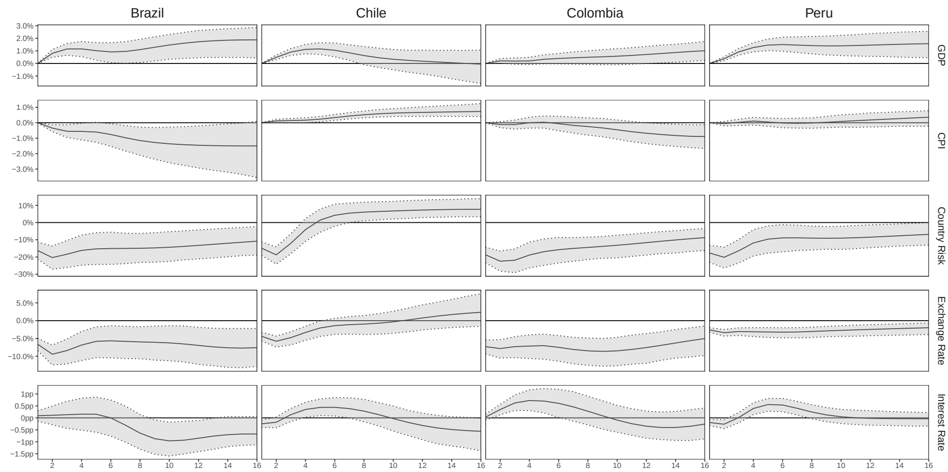

Figure 2. Impulse response functions of domestic variables to a positive shock in global demand (rightwards move in the world aggregate demand curve. The shadow areas indicate the 68% confidence interval.

direction occurs in Chile. In Peru, the CPI remains stable, which is similar to what happens in Colombian until the 7th quarter, after which it starts falling relative to pre-shock trend. This heterogeneous response may reflect differences in the intensity of the nominal exchange rate movement combined with other important structural factors, like the openness to trade. A better understanding behind this heterogeneous pattern would require a structural model calibrated to fit each country's characteristic.

The reactions of policy interest rates are also heterogeneous. It falls in Brazil after the 5th quarter, probably in response to smaller CPI inflation, while it increases in Chile, which is consistent with an upward trend in CPI. The increase in Colombian and Peruvian rates is harder to reconcile with the greater stability in their CPIs.

3.2.2 Global financial uncertainty shock

Following the sudden shock in uncertainty that reduces volatility in 58%, sovereign risks fall in a range of 35% to 40%.[15] Later, they all increase towards pre-shock path, with a faster adjustment in Chile, as shown in Figure 3.

The nominal exchange rate of Brazil, Chile and Colombia appreciates as expected by risk adjusted interest parity (by 11%, 5.8%, and 7.6%, respectively). The Peruvian currency appreciates only 1%, which is small compared to the 35% drop in its sovereign risk. In the following quarters, the Chilean and the Colombian

[15]Although apparently large, the size of the uncertainty innovation was set to produce the same 10% drop following the other shocks we study. Important yet to observe that in the context of the 2008/2009 world financial crisis, the VIX increased 134% in the 4th quarter of 2008.

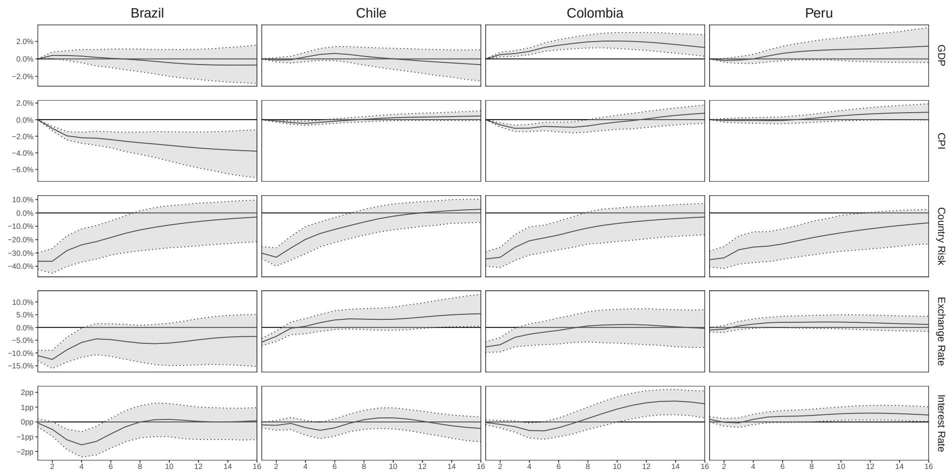

Figure 3. Impulse response functions of domestic variables to a negative shock in world economic uncertainty. Negative is related to the direction of the shock, and not its quality. As such, a negative shock to WUNC refers to a shock that reduces world financial uncertainty.The shadow areas indicate the 68% confidence interval.

currencies depreciate as they move to pre-shock path. The Brazilian currency presents a fast devaluation until the 5th quarter, oscillating afterwards around a value that is about 4% below pre-shock level.

The Colombian GDP is the only to present a significant and robust positive reaction, accumulating 2% growth in the first year and 6.6% in the second. In Brazil, the GDP increases 1.1% in the first year after the shock, but the response is not significant in any quarter. The GDP of Chile and Peru remains mostly stable along the first year, reacting positively later, but never significantly.

For the CPIs, movements in nominal exchange rates appear to be a more channel than the increase in commodity prices. The currency appreciation in Brazil, Chile and Colombia coincides with smaller CPIs. The most intense fall is in Brazil, where the currency appreciation of 11% was larger than the 10% impact rise in commodity prices. In Peru, the relative stability of the CPI also coincides with similar pattern followed by its nominal exchange rate.

3.2.3 Commodity markets/supply shock

Figure 4 shows that despite of being hit by an adverse international supply shock that elevates VIX, the sovereign risk of all countries significantly falls on impact. The drop ranges from−2.8% in Peru to−4.9% in Colombia. They increase later, reaching positive values in Chile and Peru after one year, but remaining below initial values in Brazil and Colombia. These reactions are contrary to what is expected after an increase in VIX. It appears that the commodity price index is playing a more relevant role in the determination of the sovereign spreads than the volatility at the world

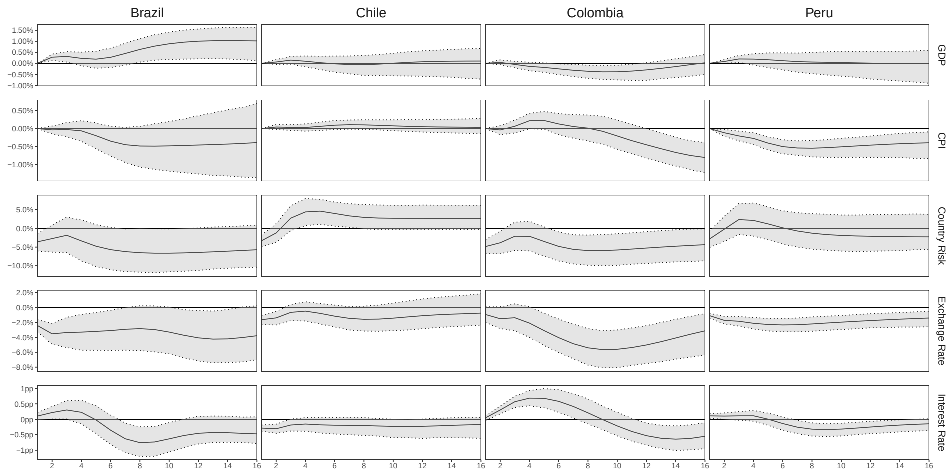

Figure 4. Impulse response functions of domestic variables to a positive supply shock. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WSUP refers to an adverse shock that moves the supply curve leftwards. The shadow areas indicate the 68% confidence interval.

financial market. More research exploiting these interactions seems a promising venue to improve our understanding of joint role played by these variables.

Higher commodity prices and smaller sovereign risk seem to work together to appreciate nominal currencies. The impact gain is 2.4% in Brazil, 1.6% in Chile, 1.1% in Peru and 0.9% in Colombia. Later, while the Chilean peso slightly depreciates, the other currencies move in opposite direction, with the Colombian peso presenting the most intense gain. In common, all four currencies remain stronger than pre-shock level, which probably reflects the high persistence in world commodity prices that remain above regular trend for long periods.

CPI reactions are again very heterogeneous, being significant since the first quarter only in Peru, where the price index moves below regular trend, restoring to standard growth rate after 2 years. In Brazil, the CPI significantly varies below pre-shock rate only after 4th quarter. The CPI pattern in these two countries seems to be strongly influenced by the currency appreciation that more than compensates the increase in commodity price. In Chile, the CPI slightly increases above regular trend until the 7th quarter, moving slower thereafter until returning to pre-shock trend. The Peruvian CPI also moves above standard trend until the 5th quarter, after which the inflation becomes smaller than pre-shock, maybe reflecting the intense currency appreciation. Policy interest rates responses are also heterogeneous, possibly reflecting the heterogeneity in CPIs responses.

GDP reactions are also heterogeneous. It contracts in Colombia, but significance occurs only in the second year, when the accumulated fall reaches 1.1% below pre-shock trend. A modest positive impact happens in Chile and Peru, where the

1-year accumulated growth reaches 0.3% and 0.5%, respectively. Brazil benefits the most from the adverse world supply shock, with GDP accumulating growth above regular trend of 0.8% in the first year and 1.5% in the second.

The impulse responses functions we report are in line to what one would expect from a general equilibrium setting of a small open emerging economy. In some cases, particularly in the presence of a worldwide adverse supply shock, directions are not so obvious, since the potential benefit of higher commodity price may be compensated by smaller global GDP and tougher global financial conditions. Indeed, the results show heterogeneous reactions of several variables revealing that a one rule fits all should be avoided when thinking about the impacts of a global supply shock. A deeper study is certainly necessary to understand the reasons behind the asymmetries we verify. But in pursuing this task, it is important that global shocks are correctly identified, which is important for interpreting and understanding the results.

3.2.4 The VAR without global finance

Commodity prices are also determined in the financial market, with derivatives and futures playing important roles in price hedging. This importance has risen over the years in a process that has been labelled the *financialization* of the commodity market. This means that commodity prices embeds the same characteristics of traditional financial assets, with prices moving at high frequency according to the forward looking behaviour of the agents. Nonetheless, commodity prices are expected to be influenced by news that not necessarily influence other assets. Similarly, the VIX, which is a volatility index based on the S&P500, does not necessarily incorporate perspectives and uncertainties that matter exclusively for the formation of commodity prices, especially because the S&P500 is compounded by the largest firms in the USA, most of them not directly involved in commodity markets.

Not including an economy-wide uncertainty measure may lead to potential misidentification of innovations in the VAR, since the commodity price shock would not be orthogonal to the commodity market. To assess this situation, we estimate a VAR without VIX (model 2) and present the impulse response functions in the Appendix D. The first thing to observe is that reactions of world GDP and commodity prices still behave as one would expect in the presence of supply and demand shocks (Figure 9), despite the absence of the VIX.

Moving to the domestic economies, the responses to a global demand shock (Figure 10) are basically when unchanged compared to those under the benchmark macro-finance model. Things are however different in the presence of a commodity price shock. The absence of the VIX generates responses (Figure 11) that are different from those in the macro-finance model. The first big change is in the reaction of country risks. The falls observed in the benchmark model are modest, being mostly significant only on impact. Now, they all drop substantially and significantly. A possible explanation for the difference is that the sudden rise in commodity price also encompasses the shock in the global uncertainty, which is not filtered away when dropping the VIX from the estimation.

The larger impact on country spreads also produces a more intense currency appreciation compared to the supply shock identified under the macro-finance model. The inflationary impact is also consistent with this larger appreciation, with CPIs falling more intensively and significantly when VIX is not included in the VAR.

Finally, the responses of domestic GDPs are also different. In particular, the reactions are more positive. In Brazil the GDP increase becomes higher and more significant. In Chile, it moves from a neutral reaction to a positive and significant increase. In Colombia it changes from a drop to a neutral reaction, and in Peru from neutrality to a non-significant increase.

3.3 Forecasting error variance decomposition – FEVD

Having understanding the nature of the global shocks and how they influence the macroeconomic variables of the emerging economies, our next step is to verify the importance of these shocks in the determination of the forecasting error variance of local variables.

3.3.1 The international bloc

Figure 5 presents the FEVD of the international variables. The left panel shows the results of the benchmark macro-finance model (model 1), while the right panel shows the FEVD when VIX is not included in the VAR (model 2).

According to the base model, the world GDP FEV is mostly explained by world demand shocks: 94%, 78%, and 57% at, respectively, 4, 8, and 16 quarters forecasting horizons. The contribution of uncertainty shocks is 4%, 9%, and 18%, while supply shocks help explaining 2%, 12%, and 25%.[16]

The relevance of uncertainty shock is not replicated for the FEV of the commodity price index, since its maximum contribution is 5%, at 4 quarters horizon. Demand and supply shocks, on the other hand, have been similarly important, with respective contributions of 46% and 49% for 4 quarters, and 55% and 42% for 16 quarters ahead forecasting.[17]

Uncertainty shocks explain close to 75% of the finance volatility FEV. Demand shocks' contribution are 18% and 14% for 4 and 16 quarters, while supply shocks' influence reach 6% and 10% at similar forecasting horizons.

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[16] Charnavoki and Dolado (2014) also find that innovations arising at the real side are important determinants of deviations of global economic activity from regular path after 2000. Our estimates, however, place higher importance to global demand shocks and verifies a non-negligible influence of uncertainty innovations, something that they do not evaluate.

[17] Alquist and Coibion (2014) also verify that worldwide aggregate factors play the most important role in accounting for historical oscillations in aggregate commodity prices.

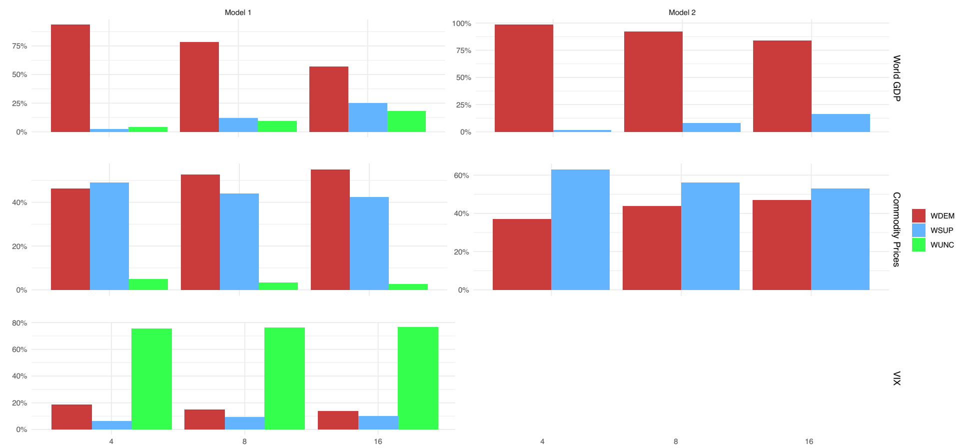

Figure 5. Forecast error variance decomposition of the international bloc. Model 1 is the benchmark, and Model 2 does not include VIX in the VAR. WDEM, WSUP, and WUNC correspond to innovations in world demand, world supply and world economic uncertainty, respectively.

When VIX is not included in the VAR, the part of FEV due to financial uncertainty in model 1 is not simply divided between supply and demand. In the case of world GDP, the contribution of supply shock drops from 25% to 15% for 16 quarters FEV. Similar pattern happens for the FEV of world commodity prices, but now it is the importance of global demand shock that shrinks relative to model 1. These results once again show how conclusions differ when the macro-finance linkage is not considered.

3.4 Domestic bloc

According to the benchmark macro-finance model, global shocks are reasonably relevant to explain domestic business cycles (Figure 6). Together they explain 27%, 33%, 17%, and 30% of 4 quarter FEV of Brazil, Chile, Colombia, and Peru, in this order. For 16 quarters FEV, their influence reaches 63%, 20%, 68%, and 41%, respectively. While these numbers confirm previous findings, our departure from the literature comes when focusing on the importance of each innovation separately. In particular, our estimates indicate that international supply shocks have exerted small influence in these countries' business cycle from 2002 to 2017.

Brazil is where the influence has been higher, however smaller than demand shocks. Specifically, we estimate that global supply shocks are responsible for 4% of the 1 year ahead FEV of the GDP and 25% in 4 years. These values correspond to 14% and 40% of the influence exerted by global shocks in the Brazilian business cycle. In the case of Chile and Peru, global supply shocks do not explain more than 2% of the GDP FEV at the horizons we consider, and in Colombia they are not

Figure 6. Forecast error variance decomposition of domestic bloc of the benchmark model. The x-axis correspond to quarters after the shocks. LUNC stands for shocks in local economic uncertainty. WDEM, WSUP, and WUNC correspond to innovations in world demand, world supply and world economic uncertainty, respectively.

responsible for more than 8%. These values represent a maximum of 12% of the aggregate influence exerted by global shocks in domestic business cycles.

Global demand shocks, on the other hand, have been the most critical international driver of business cycles in Brazil, Chile, and Peru. They explain 22% of the Brazilian 1 year FEV, 31% of the Chilean, and 28% of the Peruvian. At 16 quarters FEV, the figures are 36%, 16%, and 33%, respectively. The influence in Colombia is smaller: only 3% for 1 year and 15% for 4 years, values that are still at least double of the FEV due to supply shocks.

Colombia is the only country where international uncertainty shocks have been the major source of GDP oscillation driven by external innovation, being responsible for 13% of 1 year FEV and 47% for 4 years. The low contribution in Chile and Peru (where the maximum respective contribution of 3% and 7% is reached in 4 years FEV) is still higher than that of supply shocks.

Global shocks have also been important drivers of other macroeconomic variables. They are responsible for at least 45% of the FEV of sovereign risk and exchange rate in all countries, being particularly higher in Colombia and Peru. Their importance for CPIs and policy interest rates grows over forecasting horizons. In the case of the CPI, the contribution of innovations at world level for 4 years FEV is 59% in Brazil, 71% in Chile, 53% in Colombia, and 43% in Peru. For policy rates the influence is 42% in Brazil, 32% in Chile, 62% in Colombia, and 60% in Peru.

At world level, uncertainty shocks are the most important drivers of sovereign risks in all countries, followed by demand shocks. Global demand shocks are a very important determinant of nominal exchange rates' FEV in Brazil, Chile, and

Colombia, while supply shocks are more relevant for the nominal exchange rate of Peru. More heterogeneity happens for the FEV of CPI and policy rates, with global supply shocks exerting a more prominent role in Colombia and Peru.

Given our interest in macro-finance linkages, we also present the FEV due to domestic macroeconomic uncertainty shocks (LUNC), modeled as innovations in the equation determining the sovereign spread.[18] The tradition is to treat this as a sovereign risk premium shock, but since spreads respond to various types of speculations regarding macroeconomic policies, even those arising at the political front, we regard it as an innovation reflecting uncertainty about policies that can potentially affect the probability of sovereign default. Just as we use VIX to capture macro-finance linkages at global level, sovereign spreads do similar work domestically. The results reveal the importance of local macroeconomic uncertainty shocks for determining oscillations in local variables. Peru is where the influence is smaller, but it still determines 13% of 1 year FEV of the GDP, 16% of 2 years and 12% for 4 years FEV. In Brazil, this influence is around 20% for 8 and 16 quarters, reaching 50% and 45% in Chile and Peru after 4 years. Brazil and Chile are where the remaining variables have been mostly influenced by domestic macroeconomic uncertainty shocks.

We also analyze the FEVD by considering two popular alternatives ways of modelling the world economy. One is the model 2, without VIX in the VAR. The other is the model 3, which only considers the presence of the commodity price index as a global variable. In this last model, neither demand nor uncertainty are filtered from the commodity price index. The results are presented in Figure 7.

Excluding international variables from the VAR does not affect much the importance exerted by world shocks in the domestic variables. As a result, the global variables present in restricted versions of the model have their individual influence overstated in the FEV of domestic variables. But even in model 2, commodity price shocks still have smaller prominence than world demand shocks. An important exception occurs for the FEV of sovereign spreads, where the absence of a measure of global uncertainty increases the influence of local uncertainty shocks. This further highlights the importance of sovereign spread as a propagator of global uncertainty shocks domestically. Finally, the FEV of model 3 reinforces the point that by only including commodity prices we are potentially biasing the results, since embedded in commodity price residuals, from where we identify structural shocks, we have innovations in global demand and global uncertainty.

[18] The impulse response functions are presented in the appendix. The reactions are standard and in agreement to what is reported in the literature (Mendoza, 1991, Calvo et al., 1993, Arora & Cerisola, 2000, Bocola, 2016, Fernández et al., 2018, Uribe & Yue, 2006). After a sudden rise in local macroeconomic uncertainty (normally treated as a risk premium shock), GDP falls, exchange rate depreciates, inflation and policy interest rate rise.

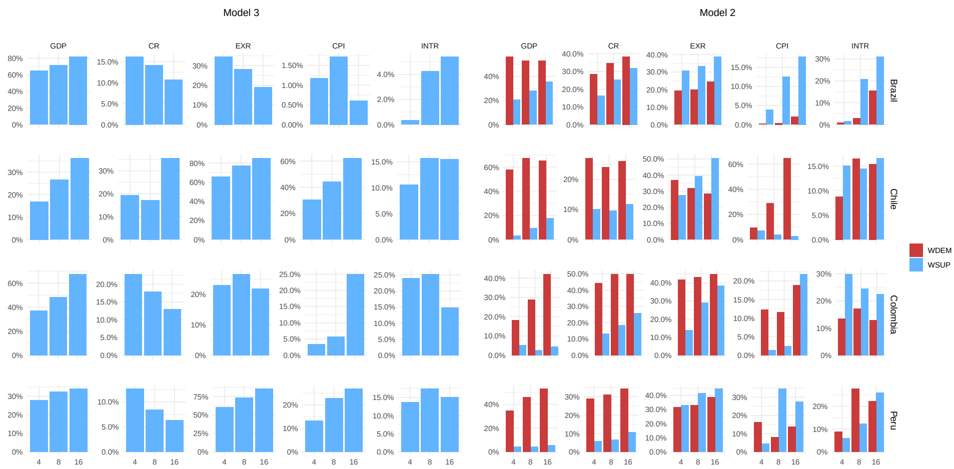

Figure 7. Forecast error variance decomposition of domestic bloc—alternative specifications. Model 2 does not include VIX in the VAR. Model 3 contains only commodity price index in the international bloc. The x-axis correspond to quarters after the shocks. WDEM and WSUP correspond to innovations in world demand and world supply (commodity market), respectively. Although we keep these notations to facilitate comparisons, in the absence of world GDP from the models is not proper to interpret innovations as supply and demand anymore.

Our results place an important challenge for the construction of theoretical models. For instance, some recent DSGE models (Drechsel & Tenreyro, 2018 and Fernández et al., 2018, for instance) arbitrarily place commodity price directly in the equation determining sovereign spreads. Constructed in this manner, it is almost obvious that simulations will show a big role played by commodity price shocks in domestic business cycle and sovereign spreads, which is exactly what they find, but not what we verify in the world macro-finance VAR.

4. Discussion

The profession has placed a lot of effort to comprehend the mechanisms and the driving forces by which global shocks affect domestic economies. Despite several advancements, features regarding the general equilibrium structure at the world level and the linkages to domestic economies are still not totally understood. This is an even bigger problem when it comes to dealing with the financial sector and uncertainty.

For instance, Shousha (2016) finds the contribution of world interest rate shocks negligible for activity fluctuations in emerging economies after controlling for the presence of commodity prices. Akinci (2013) also verifies a negligible influence (of around 5%) of US real interest rate shocks for emerging markets aggregate activity after controlling for global financial risk, which he finds to explain about 20% of output oscillation.[19] Our results, which give more support to the conclusions of Akinci (2013), exemplify how a macro-finance structure can modify results and interpretations. In this sense, Shousha (2016) seems right regarding the endogenous response of world interest rate, but misses that commodity prices also respond endogenously to other shocks in the global economy.

As another example of the importance of dealing with macro-finance linkages, our estimates show that aggregate commodity price shocks contribute far less for sovereign risks and domestic business cycles than indicated by Fernández et al. (2018), Drechsel and Tenreyro (2018), and Shousha (2016). Their conclusions seem to be influenced by the *ad-hoc* imposition of commodity prices in an equation aimed at determining the sovereign risk and by the fact that they do not filter global financial shocks away from the prices.[20] In our exercises, this filtering substantially decreases the fraction of demand and supply shocks in FEVD analyses.[21]

5. Concluding remarks

We estimate SVAR models for Brazil, Chile, Colombia, and Peru including a measure of global GDP, an aggregate commodity price index, and a measure of global economic uncertainty.

Using a SVAR model with macro-financial relations, we find that innovations to global GDP, from which we attempt to identify global demand shock, are the most important international factor influencing the GDPs of Brazil, Chile, and Peru. For Colombia we find innovations in the volatility index (VIX), from where we aim to capture global uncertainty shocks, as the most important international contributor for local business cycle.

According to our main specification, commodity price shocks have not been a major international driver of business cycle in the countries we study. Their influence become more important when the commodity price is the only international variable

[19] Akinci (2013) finds the country risk being the main propagator of global financial shocks. When country risk is assumed not to respond directly to such shocks, the variance of output, investment, and the trade balance explained by global financial risk shocks is about two-thirds smaller.

[20] Their equation determining the sovereign spread ($spread_t$) has a similar structure:

$$spread_t = \overline{spread} + \Psi\left(e^{D_{t+1}/\overline{D}} - 1\right) + \phi\left(pcomm_t - \overline{pcomm}\right) + \varepsilon_t^{\text{sovereign}},$$

where $\varepsilon_t^{\text{sovereign}}$ is a sovereign spread shock, D_t is the external debt, and $(e^{D_{t+1}/\bar{D}} - 1)$ is necessary to "close the small open economy" (Schmitt-Grohé & Uribe, 2003). The distance between the commodity price from its steady state ($pcomm_t - \overline{pcomm}$) is an *ad hoc* imposition that seems to force their results.

[21] Morana (2013) also shows the relevance of macro-finance interaction for the determination of the oil price dynamics.

in the VAR. This suggests that several works have probably taken endogenous reaction in commodity price as a direct innovation to it, inflating its relevance in the determination of domestic business cycles. A possible explanation is that the absence of a wider measure of global financial uncertainty from the model does not allow filtering away shocks that are restricted to commodity markets from those that are related to a wider global uncertainty.

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Appendix A. Data

Table 1. Data description

Country	Variable	Source	Abbreviation
International	Volatility Index or Global Economic Uncertainty	Federal Reserve of St.Louis	VIX
	All Commodity Prices	International Monetary Fund	PCOM
	Global GDP	World Bank	WGDP
Brazil	Gross Domestic Product	Banco Central do Brasil	GDP
	Consumer Price Index	Banco Central do Brasil	CPI
	J.P. Morgan's Emerging Market Bond Index Global	Banco Central de Chile	CR
	Nominal Exchange Rate	Banco Central do Brasil	EXR
	SELIC Rate	Banco Central do Brasil	INTR
Chile	Gross Domestic Product	Banco Central de Chile	GDP
	Consumer Price Index	Banco Central de Chile	CPI
	J.P. Morgan's Emerging Market Bond Index Global	Banco Central de Chile	CR
	Nominal Exchange Rate	Banco Central de Chile	EXR
	Monetary Policy Interest Rate	Banco Central de Chile	INTR
Colombia	Gross Domestic Product	Banco de la República	GDP
	Consumer Price Index	Banco de la República	CPI
	J.P. Morgan's Emerging Market Bond Index Global	Banco Central de Chile	CR
	Nominal Exchange Rate	Banco de la República	EXR
	Intervention Rate	Banco de la República	INTR
Peru	Gross Domestic Product	Banco Central de Reserva del Perú	GDP
	Consumer Price Index	Banco Central de Reserva del Perú	CPI
	J.P. Morgan's Emerging Market Bond Index Global	Banco Central de Chile	CR
	Nominal Exchange Rate	Banco Central de Reserva del Perú	EXR
	Reference Rate for Monetary Policy	Banco Central de Reserva del Perú	INTR

Appendix B. Bayesian priors for the VAR estimation

In order to estimate the Bayesian VAR we use priors suggested by Sims and Zha (1998) that were also used by Zha (1999) and Cushman and Zha (1997) in their BSVAR with block lagged restriction, as in our case. We combine two unit root priors: the Minnesota prior and the sum-of-coefficients prior. The Minnesota prior imposes the restriction that coefficients on the first lag has prior mean of 1. In the approach of Sims and Zha (1998), this is done by creating the variables such that for the ith equation, a set of $k-1$ dummy observations, indexed by $j = 1, \dots, m$, $l = 1, \dots, p$, is inserted in the data sample, with data taking the values specified by

$$\begin{aligned} y_i(r,j);\ r = 1,\dots,k-1;\ j = 1,\dots,m &= \begin{cases} \mu_1\mu_2\sigma_r/l^{\mu_4}, & \text{if } r = j, r \le m, \\ 0, & \text{otherwise;} \end{cases} \\ x_i(r,s);\ r = 1,\dots,k-1;\ s = 1,\dots,k-1 &= \begin{cases} \mu_1\mu_2\sigma_r/l^{\mu_4}, & \text{if } r = s, \\ 0, & \text{otherwise;} \end{cases} \end{aligned} \tag{1}$$

where μ_1, μ_2 and μ_4 are hyperparameters; μ_1 controls the overall tightness of A_0; μ_2 controls the relative tightness of the matrix A_l; and μ_4 controls the tightness on lag decay. These hyperparameters are set at its default values suggested by Sims and Zha (1998), which are, respectively, 1, 0.5 and 1.

The sum-of-coefficients prior is used in cases where the variables have a unit root, so this information can be reflected via a prior that incorporates the belief that coefficients on lags of the dependent variable sum to 1. In a system of m equations, l lags and k coefficients, it introduces m observations, indexed by i, of the form:

$$\begin{aligned} y(i,j);\ i = 1,\dots,m;\ j = 1,\dots,m &= \begin{cases} \mu_5\bar{y}_{0i}, & \text{if } i = j, \\ 0, & \text{otherwise;} \end{cases} \\ x(i,s);\ i = 1,\dots,m;\ s = 1,\dots,k &= \begin{cases} \mu_5\bar{y}_{0i}, & \text{if } i = j, \text{ all } l, \\ 0, & \text{otherwise;} \end{cases} \end{aligned} \tag{2}$$

where $\bar{y}_{0i}$ is the average of initial values of the variable i and μ_5 is a hyperparameter that controls the weight of the prior. For instance, as $\mu_5 \to \infty$, the model tends to a form that can be expressed entirely in terms of differenced data. In this paper this hyperparameter is set to its default value of 1.

Appendix C. International bloc: Alternative ordering

The international bloc in the benchmark model is ordered with World GDP coming first, followed by VIX and commodity price index. Here, we invert the order between VIX and the commodity price index. According to such identification scheme, an adverse shock to the world commodity market would cause a drop in volatility, as displayed in the middle column of Figure 8. This reaction is the opposite one would expect from an adverse supply shock, so it does not make sense to adopt it if one is willing to interpret shocks as demand, uncertainty and supply.

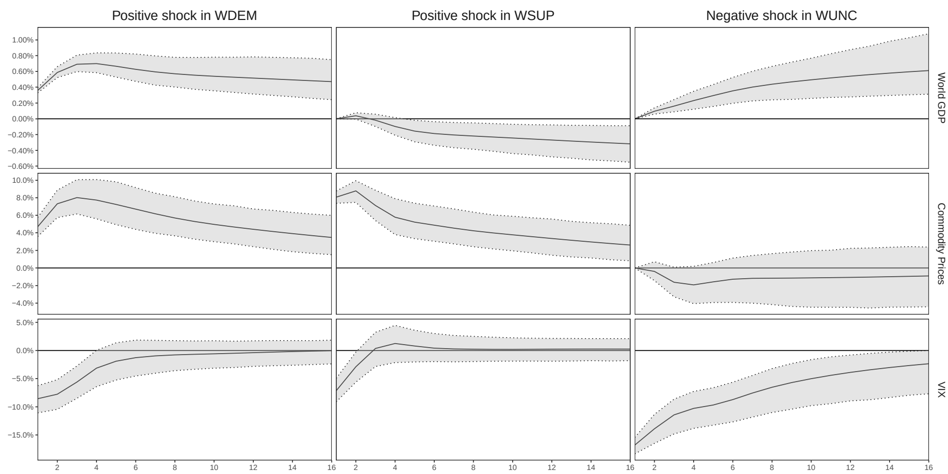

Figure 8. Impulse response functions of the international variables from an alternative ordering with PCOM coming before VIX. WDEM, WSUP, and WUNC represent, respectively, world demand, world supply and, world financial uncertainty. Negative and positive are related to the direction of the shock, and not its quality. As such, a negative shock to WUNC refers to a shock that reduces world financial uncertainty, while a positive shock in WSUP refers to an adverse shock to the commodity markets that moves the supply curve leftwards.

Appendix D. Impulse response functions of alternative models

We present the impulse response functions of two alternative models mentioned in the text.

Model 2 Excludes VIX from the model, so the international bloc is formed be the world GDP and the commodity price index.

Model 3 International bloc contains only the commodity price index.

Model 2

VIX is excluded from the VAR. The remaining variables and identification remain as in the benchmark.

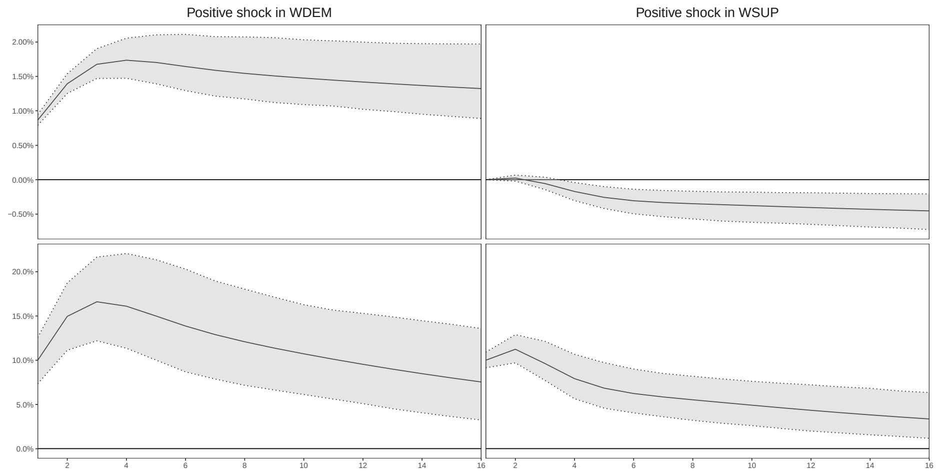

Figure 9. INTERNATIONAL BLOC
Response of international variables. WDEM and WSUP represent, respectively, world demand and world supply. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WSUP refers to an adverse shock to the commodity markets that moves the supply curve leftwards and a positive shock in WDEM refers to a shock that moves the demand curve rightwards.

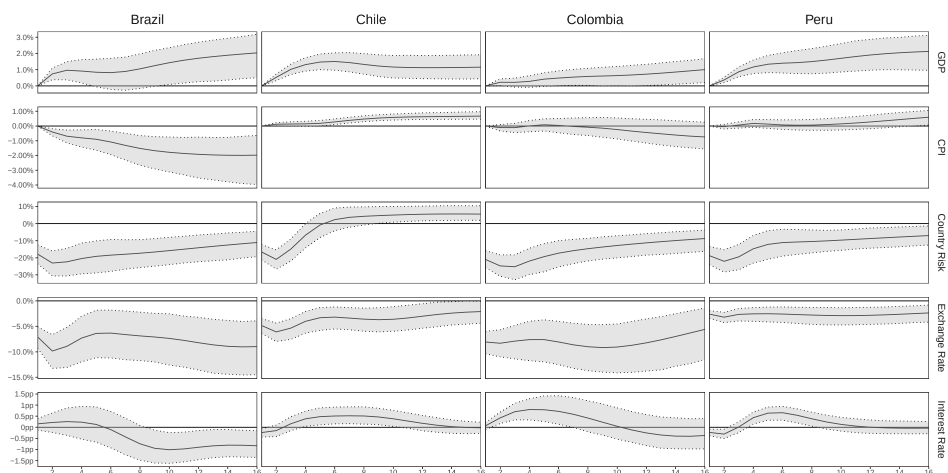

Figure 10. POSITIVE WORLD DEMAND SHOCK
Response of domestic variables to a positive shock in global demand. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WDEM implies that the demand curve moves rightwards.

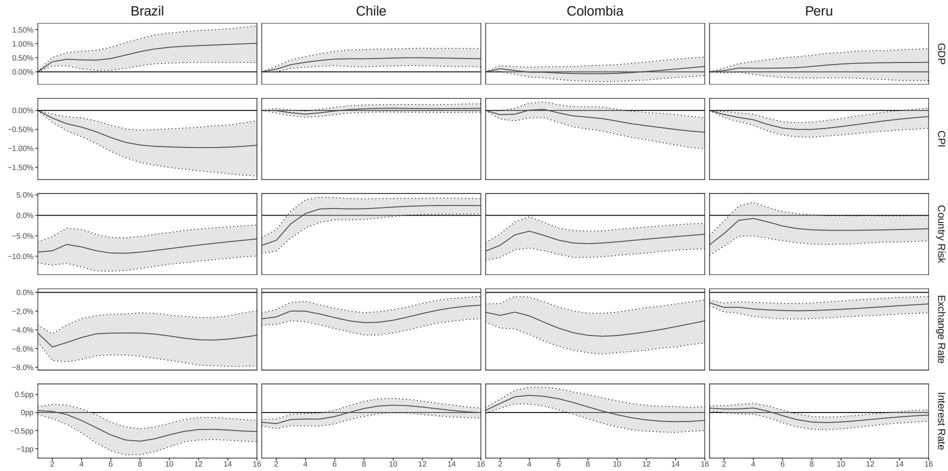

Figure 11. Adverse world supply shock
Response of domestic variables to a positive supply shock. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WSUP refers to an adverse shock to the commodity markets that moves the supply curve leftwards.

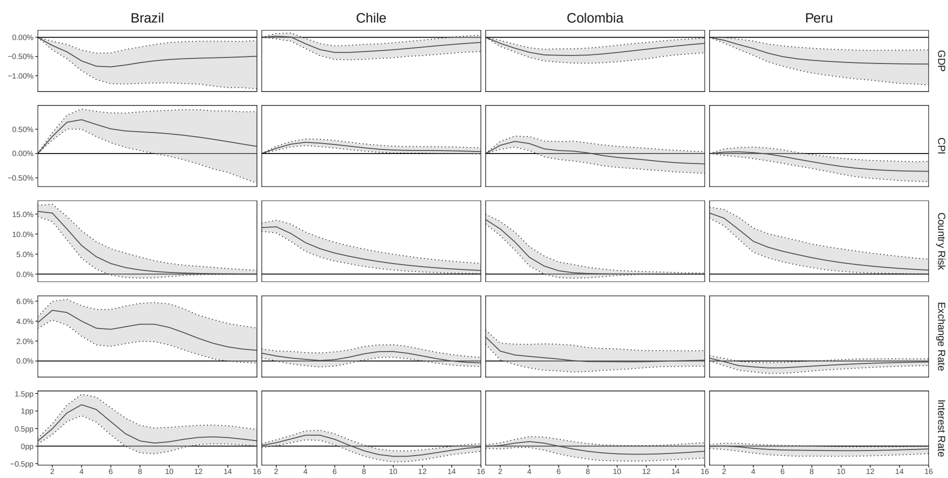

Figure 12. Positive shock to the domestic macroeconomic policy uncertainty
Response of domestic variables to a positive shock in local uncertainty. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in LUNC implies an increase in local uncertainty.

Model 3

In this specification, the commodity price index is the only international variable. variables and identification in the domestic bloc remains as in the benchmark.

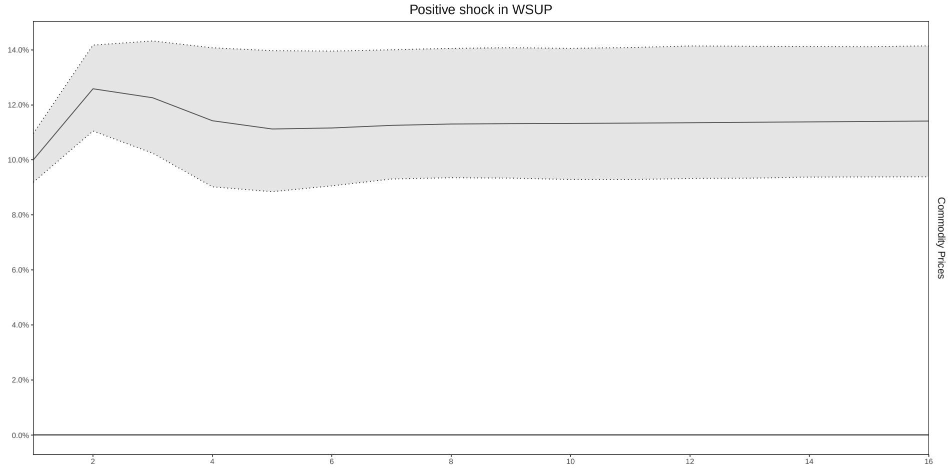

Figure 13. International bloc
Response of international variables. WSUP represent world supply. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WSUP refers to an adverse shock to the commodity markets that moves the supply curve leftwards.

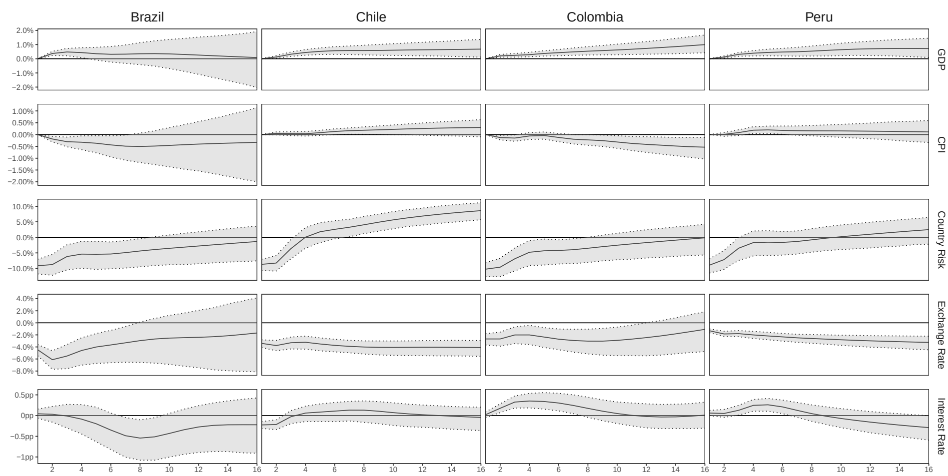

Figure 14. Positive shock in commodity price index
Response of domestic variables to a positive supply shock. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in WSUP refers to an adverse shock to the commodity markets that moves the supply curve leftwards.

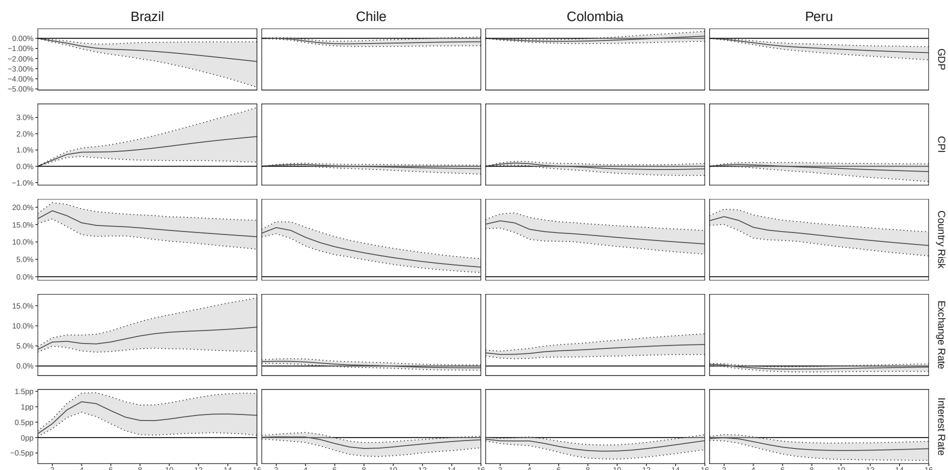

Figure 15. Positive shock to the domestic macroeconomic policy uncertainty
Response of domestic variables to a positive shock in local uncertainty. Positive is related to the direction of the shock, and not its quality. As such, a positive shock in LUNC implies an increase in local uncertainty.

Appendix E. FEVD

Model 2

Forecast error variance decomposition of the model that excludes VIX from the international bloc.

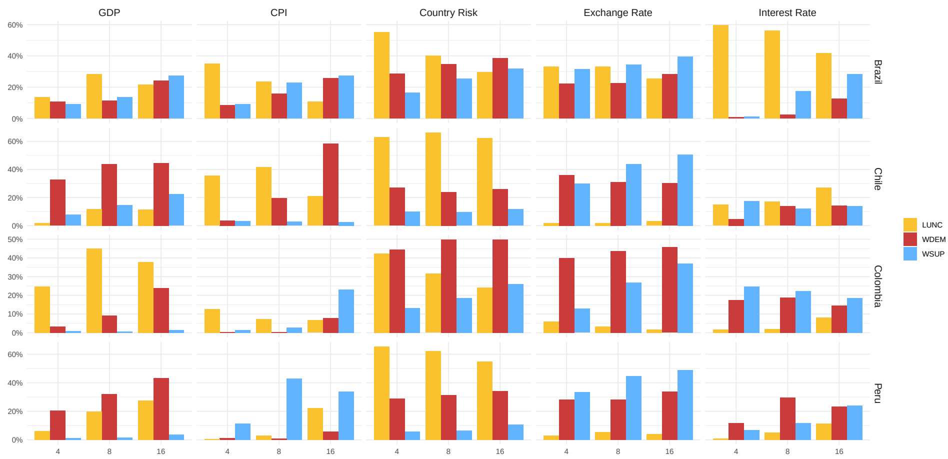

Figure 16. Forecast error variance decomposition of domestic bloc of specification that exclude VIX from the international bloc. The x-axis correspond to quarters after the shocks. LUNC stands for shocks in local economic uncertainty. WDEM, and WSUP, correspond to innovations in world demand, and world supply, respectively.

Model 3

Forecast error variance decomposition of model with only the commodity price index in the international bloc.

Figure 17. Forecast error variance decomposition of domestic bloc of model that contains only commodity prices in the international bloc. The x-axis correspond to quarters after the shocks. LUNC stands for shocks in local economic uncertainty and WSUP correspond to innovations in world supply. Although we keep these notations to facilitate comparisons, in the absence of world GDP and VIX, it is not proper to interpret innovations as supply shocks anymore.

Appendix E.1 Full FEV decomposition of GDP

Modelo 1 – Benchmark

Forecast error variance decomposition of domestic GDP considering all shocks in the specification presented in the text.

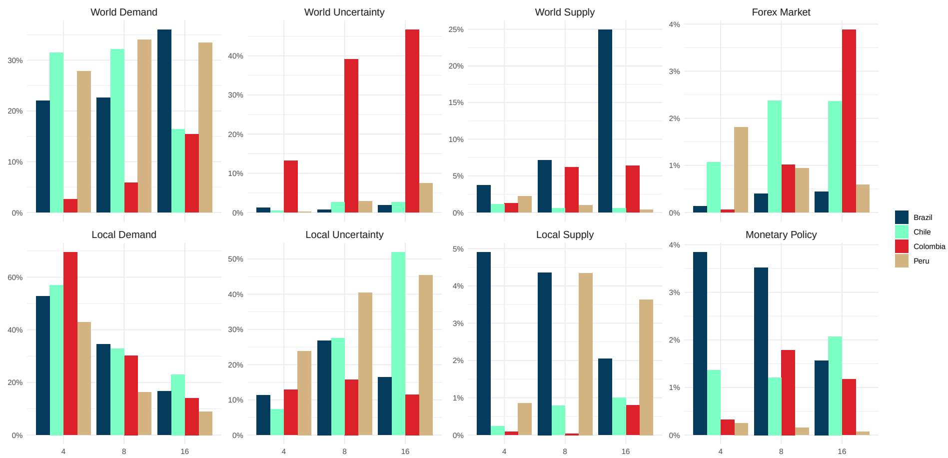

Figure 18. Forecast error variance decomposition of GDP considering all shocks in the benchmark model. Each plot represents one shock. The x-axis correspond to quarters after the shocks.

Model 2

Forecast error variance decomposition of domestic GDP considering all shocks. This specification is the same as the benchmark model, but with an alternative identification in which the real bloc reacts contemporaneously to international shocks.

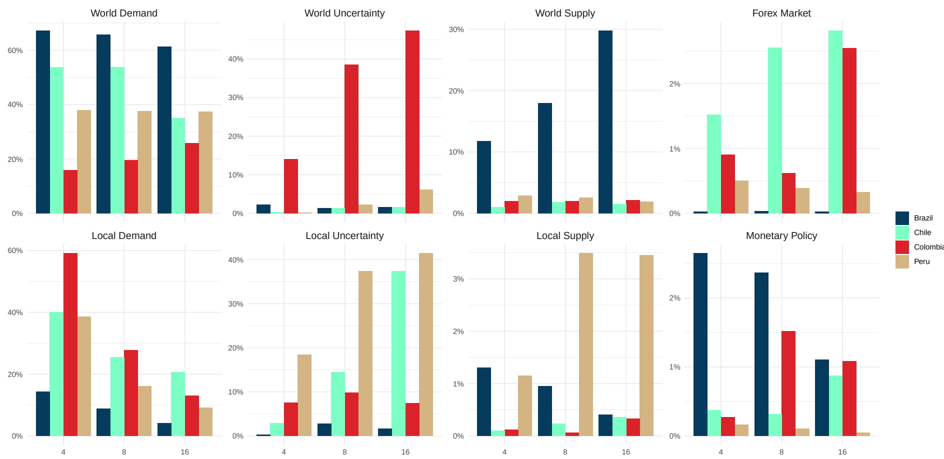

Figure 19. Forecast error variance decomposition of GDP considering all shocks in Model 2, which have an alternative identification. Each plot represents one shock. The x-axis correspond to quarters after the shocks.

Model 3

Forecast error variance decomposition of domestic GDP considering all shocks. This specification excludes the VIX index from the international bloc.

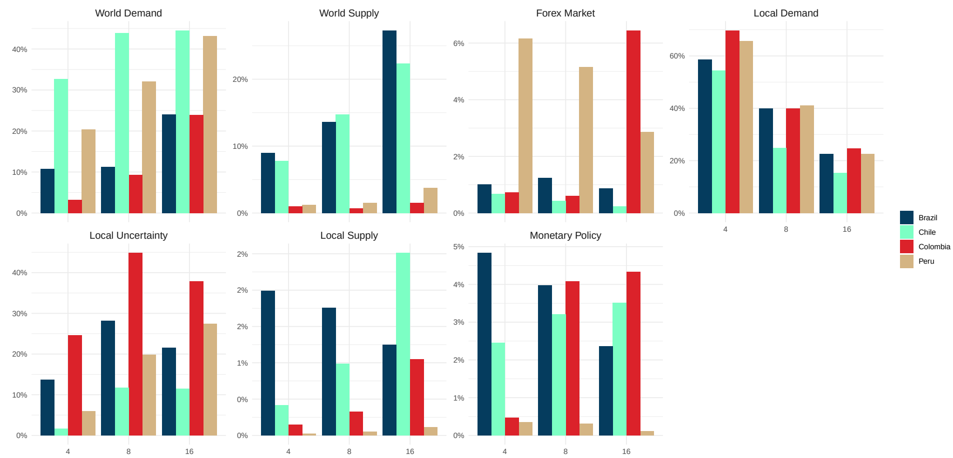

Figure 20. Forecast error variance decomposition of GDP considering all shocks in Model 3, which excludes the VIX index from the international bloc. Each plot represents one shock. The x-axis correspond to quarters after the shocks.