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

Sergio Serván Lozano*

May 22, 2019

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.

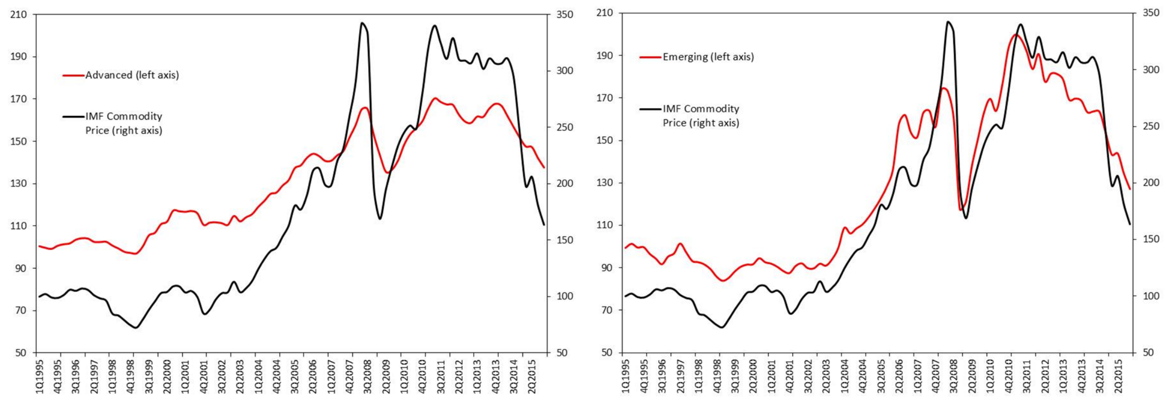
Key words: Commodity Prices, Panel Vector Autoregressions, Bayesian Methods

*I would like to thank Richard Evans and Christopher Roark for their suggestions to improve this work. All remaining errors are mine. Email address: sservanlozano@uchicago.edu

1 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.

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

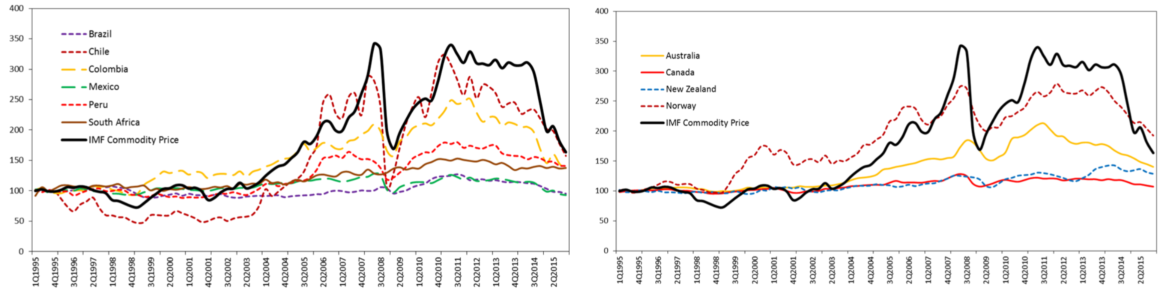
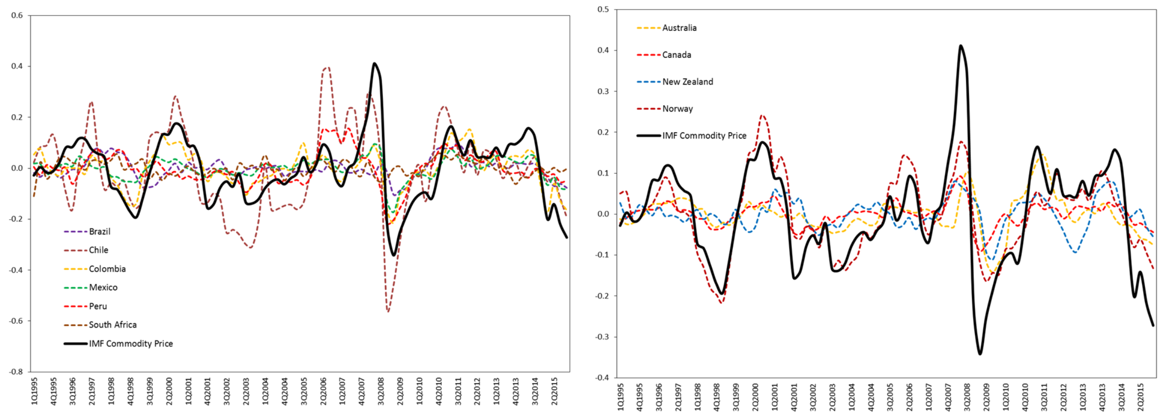


Figure 3: Country's Terms of Trade Indices and IMF Commodity Price Index (1995 = 100)
(Cyclical Component)



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

64% of Colombia's exports, 41% of Canada's, and 80% of Norway's[1]. 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[2]. 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).

[1]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).

[2]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.

2 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[3].

2.1 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

[3] 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

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

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 coefficients, 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 Ξ_1, Ξ_2, Ξ_3, Ξ_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[4].

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 $\upsilon_t = E_t + W_t u_t$.

[4]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:

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

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:

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

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

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

2.2 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.

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

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

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

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

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

2.3 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.

3 Bayesian Estimation

3.1 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

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

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 $\overline{\theta}_{t|T}$ 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 $\varepsilon \sim N(0,1)$ 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.

3.2 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.

3.3 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

$$IR^j_Y\left(t, h\right) = E\left(Y_{t+h} \mid F^1_t\right) - E\left(Y_{t+h} \mid F^2_t\right), \quad h = 1, 2, \ldots$$

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.

4 Results

4.1 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.

4.2 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

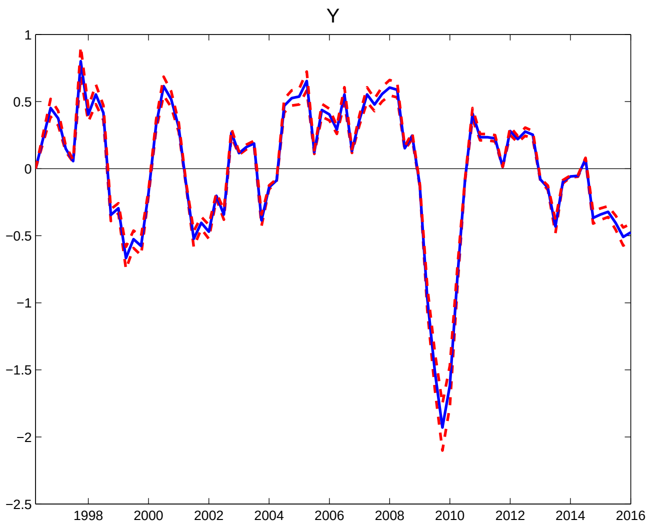
Model	Description	$\ln f\left(Y^T \mid M_i\right)$
M_1	Baseline Model ($p = 1, q = 1$)	-4168.8
M_2	No Country Component	-4172.2
M_3	No Variable Component	-4232.5
M_4	Alternative model ($p = 2, q = 2$)	-4561.6
M_5	Alternative model ($p = 2, q = 1$)	-4400.2

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.

4.3 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

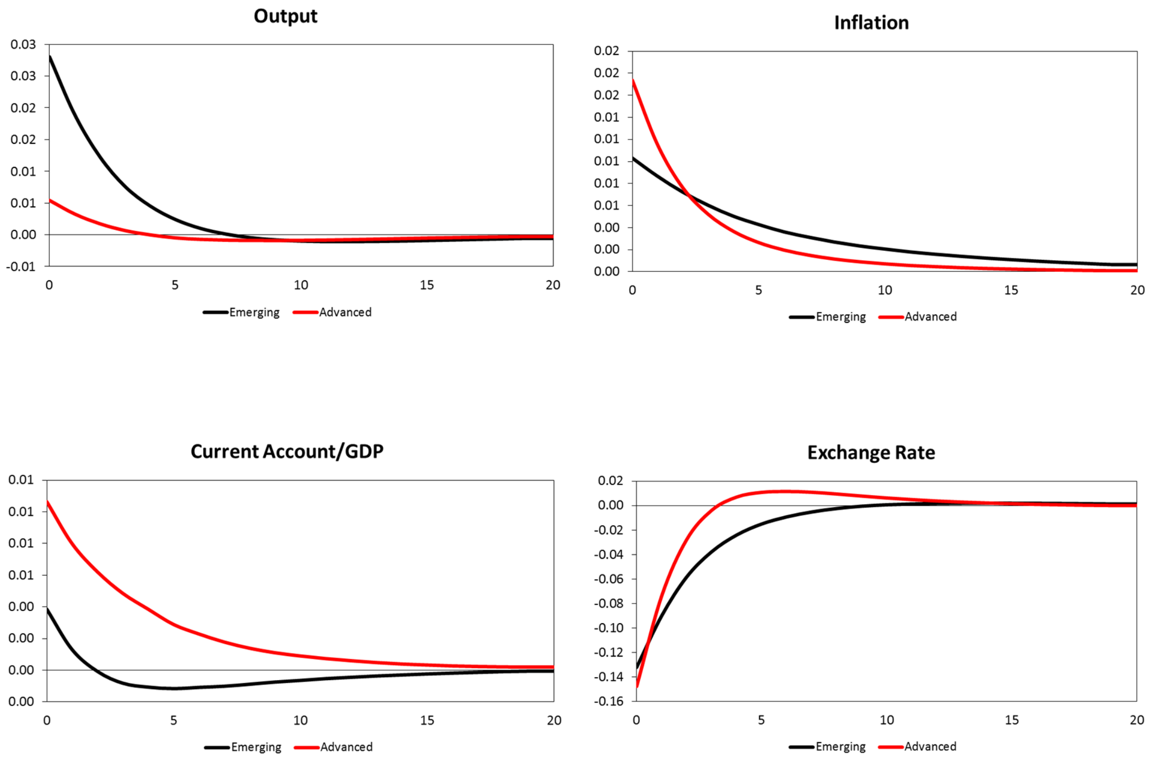


The previous indicator shows the average ups and downs of GDP growth and it is significant for the whole sample given the confidence bands. In particular, it captures the recession of 2008 and the decline in GDP growth experienced by most small open economies in 1998 due to the Russian financial crisis. 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.

4.4 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 3.3. For each horizon (from 0 to 20), the graphs show the simple average of the individual responses of each variable across countries.

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[5]. Unlike the response observed for the exchange

[5]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.

4.5 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.

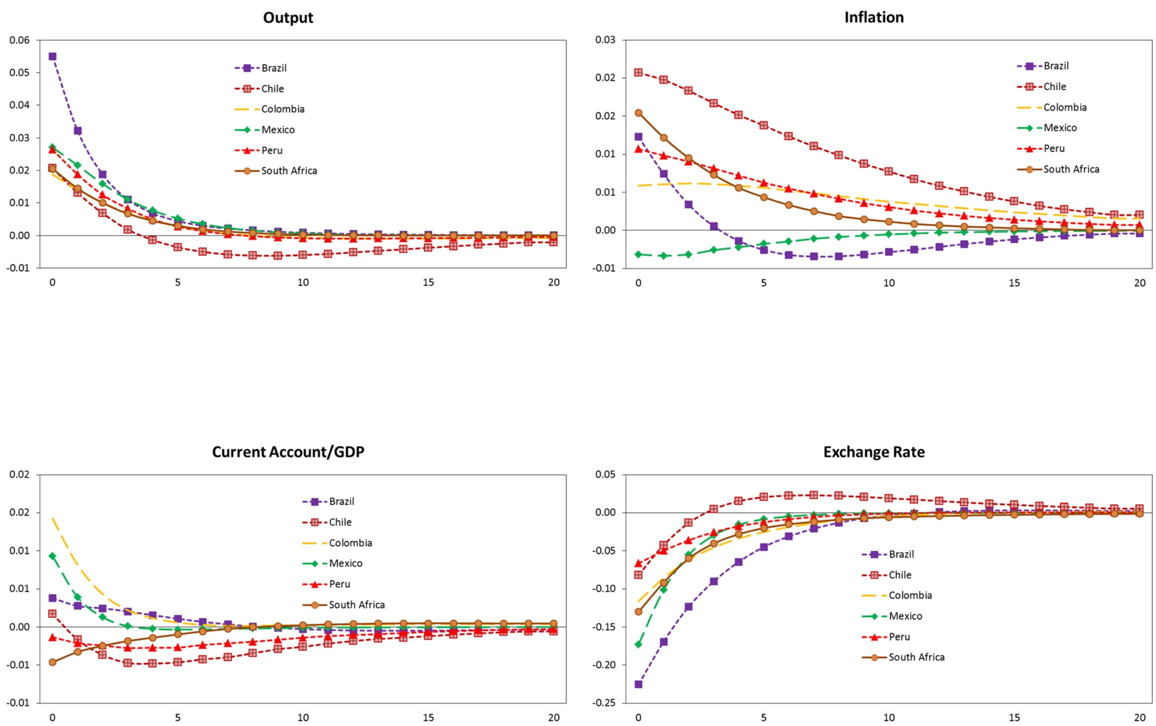
the trade balance. After an increase in commodity prices, as we stated, exports respond more than imports; thus producing an improvement in the trade balance. Although my empirical model does not take into account explicitly the trade balance, there is evidence this effect is present for Peru (for example, 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.

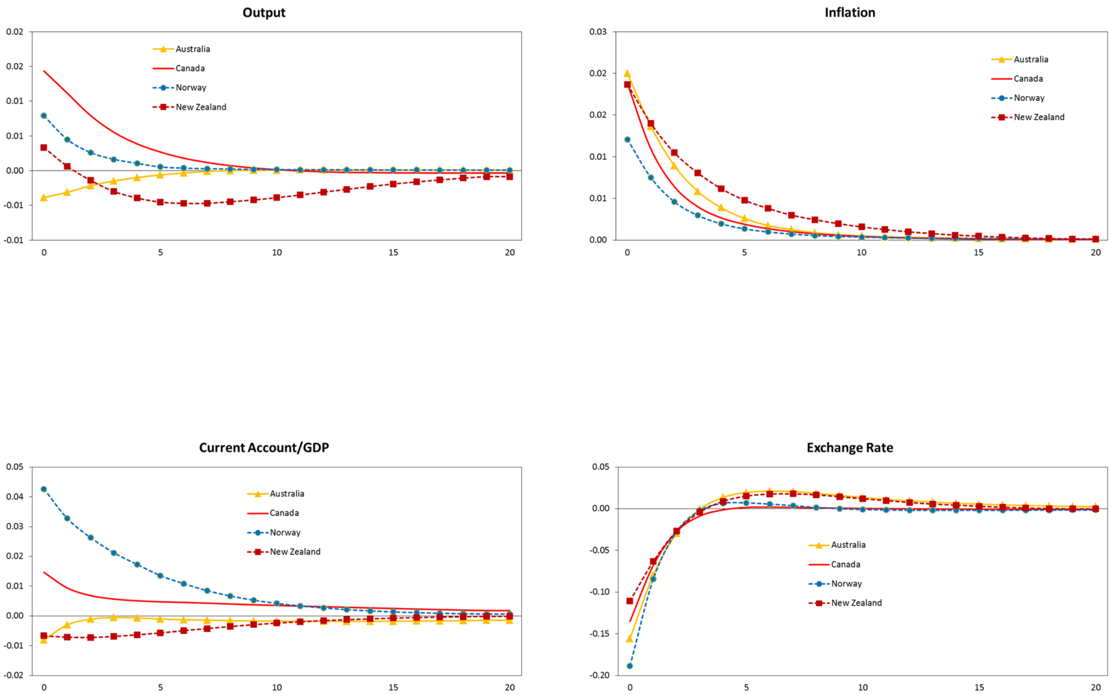
Within advanced economies we see less heterogeneity in the responses. For instance, the responses of exchange rate and inflation are quite similar among Australia, Canada, Norway, and New Zealand. The main difference appears in the response of the current account and output. For example, Australia's 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 3.3. 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

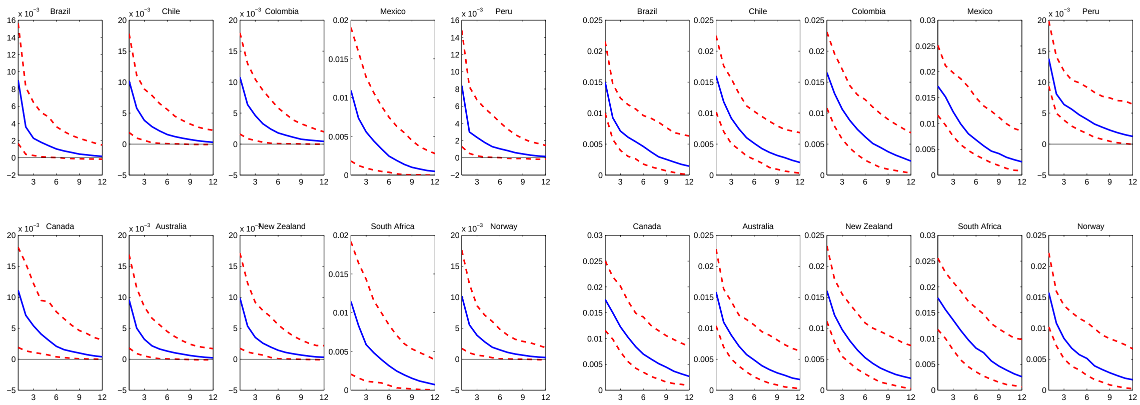


Note: Impulse Responses are computed following the procedure describe in section 3.3. For each horizon (from 0 to 20) and country, the graphs show the simple average responses of each variable.

4.6 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.

References

Andrews, D. and D. Rees (2009), Macroeconomic volatility and terms of trade shocks. RBA Research Discussion Paper No 2009-05.

Blattman, C., J. Hwang and J.G. Williamson (2007), 'Winners and losers in the commodity lottery: The impact of terms of trade growth and volatility in the periphery 1870-1939', *Journal of Development Economics* **82**, 156–179.

Bleaney, M. and D. Greenaway (2001), 'The impact of terms of trade and real exchange rate volatility on investment and growth in sub-saharan africa', *Journal of Development Economics* **65**, 491–500.

Canova, F. and M. Ciccarelli (2009), 'Estimating multicountry var models', *International Economic Review* **50**(3), 929–959.

Canova, F. and M. Ciccarelli (2012), 'Clubmed? cyclical fluctuations in the mediterranean basin.', *Journal of International Economics* **82**, 162–175.

Canova, F., M. Ciccarelli and E. Ortega (2007), 'Similarities and convergence in g-7 cycles', *Journal of Monetary Economics* **54**, 850–878.

Canova, F., M. Ciccarelli and E. Ortega (2012), 'Do institutional changes affect business cycles? evidence from europe', *Journal of Economic Dynamics and Control* **36**, 1520–1533.

Cashin, P., F. Céspedes and R. Sahay (2004), 'Commodity currencies and the real exchange rate', *Journal of Development Economics* **75**, 239–268.

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

Chib, S. and E. Greenberg (1995), 'Hierarchical analysis of sur models with extensions to correlated serian errors and time-varying parameter models', *Journal of Econometrics* **68**, 339–360.

DeGregorio, J. and F. Labbé (2011), Copper, the real exchange rate and macroeconomic fluctuations in chile. Documento de Trabajo No 640, Banco Central de Chile.

Gómez-Gonzáles, P. and D. Rees (2013), Stochastic terms terms of trade volatility in small open economies. RBA Research Discussion Paper No 2009-05.

Koop, G. (2003), *Bayesian Econometrics*, John Wiley and Sons Ltd.

Schmitt-Grohé, S and M. Uribe (2018), 'How important are terms-of-trade shocks?', *International Economic Review* **59**, 85–111.

Shousha, S. (2016), Macroeconomic effects of commodity booms and busts: The role of financial frictions. Mimeo Columbia University.

Tashu, M. (2015), Drivers of perus equilibrium real exchange rate: Is the nuevo sol a commodity currency? IMF - Working Paper 15/26.

Williamson, J.G. (2008), 'Globalization and the great divergence: Terms of trade booms, volatility and the poor periphery, 1782-1913', *European Review of Economics History* **12**, 355–391.

Zellner, A. (1971), *An Introduction to Bayesian Inference in Econometrics*, reprinted in Wiley Classics Library Edition, 1996, New York, NY: Wiley.