Shock Dependent Exchange Rate Pass-Through - An Analysis for Latin American Countries

Southern Cone Department

José Luiz Rossi Júnior
João Paulo Madureira Horta da Costa

DISCUSSION PAPER Nº IDB-DP-01033

September 2023

Shock Dependent Exchange Rate Pass-Through - An Analysis for Latin American Countries

Abstract

This paper investigates the exchange rate pass through considering the source of the shocks that hit the economy. With a Bayesian Global VAR model, the exchange rate pass-through is analyzed for 5 Latin American countries: Brazil, Chile, Colombia, Mexico and Peru. The model is estimated with Bayesian techniques and is identified by sign and zero restrictions. The BGVAR estimation enable us to allow spillover between countries mimicking the real conditions when the shocks hit the economies. Four domestic shocks for each Latin American countries are considered: an exchange rate shock, a risk premium shock, a monetary policy shock and a demand shock. The demand shock has the highest exchange rate pass-through for all the countries and the exchange rate shock has the lowest one. Additionally, two regional shocks are considered: a regional monetary policy shock, an event that all the region rises its interest rate and a regional risk premium shock, where the risk premium rises at the same time. For almost of the countries, the exchange rate pass-through coming from those regional shocks are lower than its domestic counterpart shock. Finally, we investigate two global shocks, an uncertainty shock and a global commodities/demand shock. The uncertainty shock decreases the economic activity and depreciates the exchange rate with a negative exchange rate pass-through in the middle term. The commodities/demand shock increases the economic activity and appreciates the exchange rate pass-through, having a negative or neutral exchange rate pass-through over the time.

Keywords: Exchange rate pass-through, Inflation, Latin America, BGVAR

JEL Classification: E31, E32, E37, F41

1 Introduction

Exchange rate pass-through is a topic that always come to the discussion when the exchange rate volatility arises. The emerging countries faces this volatility environment in a more periodicity time and understanding its consequences is imperative for the policymakers. The exchange rate pass-through (ERPT henceforth) is defined as the degree of the exchange rate movements that are transmitted to the domestic price level. This ERPT definition explains much of the importance to understand how it evolves through the economy and what are the key factors that determine its magnitude. For example, the Central Bank should comprehend the ERPT in order to set the interest rate and avoid a wrong response of the monetary policy. The ERPT has also implications on investment and savings decisions and current account balances.

The literature presents a wide pool of methodologies to investigate the exchange rate pass-through. Campa and Goldberg (2005), for instance, use single equations to investigate how the exchange rate movements impact the import prices. They control for variables that might affect the degree of the pass-through and found evidence that the pass-through is less than 1 (incomplete) with macroeconomic variables such as the volatility of the exchange rate and the average inflation being important to explain the cross country differences. With an open-economy macroeconomic model, Choudri and Hakura (2006) also have found strong evidences that the average inflation determines the degree of the pass-through dominating others macroeconomic variables. Using a model of firm behavior including staggered prices, Taylor (2000) emphasizes the importance of a low and stable inflation scenario for a low pass-through environment. In his model, the firms set prices for future periods taking into account the costs that may occur during these periods. In a high inflation environment, the cost increases tend to be more persistent and the firms are more prone to adjust their prices to any cost pressure, including the depreciation of the exchange rate.

The volatility of the inflation rate is consensual as one of the main factors that influences the degree of ERPT. However, it seems that all monetary environment is crucial since having inflation expectations anchored is also very important. Mishkin (2007, 2008) , De Mendonça and Tiberto (2017) suggest that having anchored inflation lesser the degree of the ERPT. In a panel data analysis for developing countries, De Mendonça and Tiberto (2017) argue that shocks to prices are mitigated when the inflation expectations are anchored, particularly shocks that comes from the exchange rate.

The business cycle position is another key variable to determine the degree of the ERPT. Correa and Minella (2010) employing thresholds models show us that when economy is growing faster, the degree of the ERPT is higher. Donayre and Panovska (2016), Przystupa and Wróbel (2011), among others also find evidence that an economy in a expansion cycle have higher ERPT. A possible reason for this result is due to a favorable scenario to raise prices when the economy is growing faster as the people might be more willing to accept prices increase.

As we can see, there are some stylized facts about the variables that influence the degree of the exchange rate pass-through. Notwithstanding, a new look has recently began to investigate the ERPT: the source of the exchange rate movements. The idea here is to extract information about the kind of shocks which are hitting the exchange rate since the others variables responses also depend on this shock. A positive demand shock, for example, has different implications for the output and the inflation rate than a monetary policy shock. As those variables are key to determine the degree of the ERPT, their usual response provides information to what we can expect to the ERPT. This shock dependent ERPT studies was pioneered first by Shambaugh (2008) but without a closer look of its determinants.

Based in a general open economy framework, Forbes et al. (2018) provide intuition about how the exchange rate movements translate to the domestic prices taking under consideration what kind of shock hit the economy. Forbes et al. (2018) highlight the relevance of identifying the source of the shock since the reaction of the output, the monetary policy and also the persistence of the exchange rate movement can explain better the magnitude of the ERPT. Using a VAR with sign restrictions for the United Kingdom, they find out that the domestic demand shock has the lowest degree of ERPT and the monetary policy the highest one. This finding for the domestic demand shock reflects the idea that after an appreciation of the exchange rate, the importers face a strong demand and have less incentive to reduce prices. But it is worth mentioning that his result for the demand shock considers an exchange rate appreciation and his finding may not remain with a depreciation event.

There is a growing literature in this area of shock dependent ERPT in the recent years. Studies for specific countries or group of countries have emerged as Comunale and Kunovac (2017) do for euro area members, Corbo (2018) for Sweden, An, Wynne, et al. (2020) for Japan. It is interesting to note that all of those papers employ the VAR with sign restriction approach since this methodology facilitates the identification of the source of the shock. In this line, Ha et al. (2020) is the only one who applies a FAVAR model to analyse the shock dependent ERPT for forty seven countries. Following this idea to include more countries, Forbes et al. (2020) presents a more complete study covering a pool of countries and also finds that the demand and the monetary policy shock have the lowest and higher degree of the pass-through respectively. However, those papers that consider more than one country do not link the countries with each other, and analyse the shock dependent ERPT individually.

This paper contributes to the literature by applying a methodology to differentiate the shock by its origins divided in domestic, regional and global events to analyse the ERPT. We apply the Global VAR (GVAR) approach that is build up to analysing the shocks spillover between countries, taking under consideration the relationship between them. In this sense, the Global VAR (GVAR) representation allow us to use the VAR either for a single country or for a group of countries and makes possible to identify the shock by country and regions. Hence we can pick up a complete picture of the shock with a Global model in a way that has not been done before since the literature usually deals with individual country models or big aggregate models as FAVAR. We apply our methodology for a set of 5 Latin American countries - Brazil, Chile, Colombia, Mexico and Peru. These group of country make a good case study since are all countries besides its geographical location, share several macroeconomic similarities with floating exchange rate regimes within an inflation targeting regime and are significant trade partners.

The paper is organized as follows: the econometric methodology and the data sample is shown in the next section. The third section presents the identification strategy followed in the fourth section by the results of the estimation including the Impulse Response Functions and a measure of the ERPT found. Finally it concludes in the 5th section.

2 Econometric methodology and data sample

WE will use the Bayesian Global Structural Vector Auto-regression (BGSVAR) methodology to estimate the exchange rate pass-through. The BGSVAR methodology is the VAR estimated for a group of countries (or entities) allowing spillover between them with Bayesian techniques identified by sign and zero restrictions[1]. To better understand, this methodology will be explained by parts: first showing its basic structure, the Global VAR (GVAR) approach, then the Bayesian inference applied to estimate it and finally the inclusion of the structural identification strategy.

- BGSVAR: specification.

The GVAR methodology was developed by Pesaran et al. (2004) and has been created to evaluate shocks spillover between countries. Theoretically, this kind of analysis could be done by VARs, however due to the quick loss of degree of freedom as more variables are included, the VAR might be unfeasible to make this inference. As so, Pesaran et al. (2004) proposed a way to estimate VARs including spillover effect and at same time deal, somewhat, with the loss of degrees of freedom characteristic.

Let us consider that there are $i+1$ countries with x endogenous variables. Each of those countries are estimated with their own factors (the x endogenous variables) and also with the weak exogenous variables x^* representing the external variables from the country i. For presentation purposes let's assume the following GVAR model with lag 1 for the country i:

$$x_{it} = a_{i0} + a_{i1_t}t + \phi_i x_{it-1} + \Lambda_{i0} x^*_{it} + + \Lambda_{i1} x^*_{it-1} + \varepsilon_{it} \tag{1}$$

where: a_{i0} and $a_{i1_t}t$ are the constant and deterministic time trend of the VAR model for the country i , x is a vector $(k_i \times 1)$ of endogenous variables, x^* is a vector $(k^*_i \times 1)$ of foreign (weak exogenous) variables, ε_{it} is a $(k_i \times 1)$ vector of idiosyncratic shocks and ϕ_i is a matrix $(k_i \times k_i)$ of

[1] Actually, in the literature the BGSVAR is called as BGVAR without the term S. However, we inserted this term to highlight the identification strategy possibility.

lagged endogenous coefficient. The idiosyncratic shock can be decomposed in a time varying variance-covariance matrix $\Sigma_{it} = V_i S_{it} V_i^{'}$ with V being a lower triangular matrix of dimension $k_i \times k_i$ with elements $v_{ij,n} = (j = 2, ..., k_i; n = 1, ..., j-1)$ and S being a diagonal matrix given by: $S_{it} = diag(\varepsilon^{s_{i1,t}}, ..., \varepsilon^{s_{ik,t}})$. The Λ_{i0} and Λ_{i1} are matrices $(k_i \times k_i^*)$ of contemporaneous and lagged coefficients of the foreign variables. Note that if Λ_{i0} = Λ_{i1} = 0, equation (1) defines a VAR(1), but if we allow the presence of foreign variables, Λ_{i0} and $\Lambda_{i1} \neq 0$, we turn to have a VARX(1,1) with the foreign variables entering in the model contemporaneously and lagged.

The weak exogenous variables is defined in the GVAR model as:

$$x_{it}^* = \sum_{j \neq i}^{N} \omega_{ij} x_{jt} \tag{2}$$

where ω_{ij} is a link matrix that is formed by the weighted trade flows or any other economic variables that represents the bilateral connection between the countries. It is worth noting that this bilateral linkage ω_{ij} are exogenous (and fixed) and the weak exogenous variables x_t^* is a function of x_t, allowing to be determined endogenously within the global system. Additionally, we must have $\sum_{j=0}^{N} \omega_{ij} = 1$.

The estimation strategy of the GVAR comprehends two stages: first it estimates the VARs for the individual countries assuming that the residuals ε_{it} is uncorrelated between the countries. Second combine the individual VARs with the weak exogenous variables to obtain a Global representation of the model. To achieve a Global representation of the VARs, define z_t as:

$$z_{it} = \begin{bmatrix} x_{it} \\ x_{it}^* \end{bmatrix} \tag{3}$$

If we restate the model (1) with left hand size contemporaneous terms, we have:

$$A_i z_{it} = a_{i0} + a_{1t} t + B_i z_{it-1} + \varepsilon_{it} \tag{4}$$

with $A_i = (I_k, -\Lambda_{i0})$ and $B_i = (\phi_i, -\Lambda_{i1})$. Recalling (2) it is possible to re-write the equation (4) using a W link matrix:

$$A_i W_i x_{it} = a_{i0} + a_{1t} t + B_i W_i x_{it-1} + \varepsilon_{it} \tag{5}$$

which $A_i W_i$ and $B_i W_i$ are both $(k_i \times k)$ dimensional matrices. Stacking these matrices for all countries in the model leads to:

$$G x_t = a_{i0} + a_{1t} t + H x_{t-1} + \varepsilon_t \tag{6}$$

where $a_{i0} = [(a_{00})', ..., (a_{N0})']$, $a_1 = [(a_{01})', ..., (a_{N1})']$, $G = [(A_0 W_0)', ..., (A_N W_N)']$, $H = [(B_0 W_0)', ..., (B_N W_N)']$ and $\varepsilon_t = [\varepsilon_{0,t}', ..., \varepsilon_{N,t}']$. Remind that we have assumed the nonzero contemporaneous shocks correlation between countries, hence $\varepsilon_t = [\varepsilon_{0,t}', ..., \varepsilon_{N,t}'] \sim \mathcal{N}(0, \Sigma_\varepsilon)$ with

Σ_ε denoting a block diagonal matrix. As G is a full rank matrix and hence non-singular, we can multiply (6) from the left by G^{-1} yielding:

$$\begin{aligned} x_t &= G^{-1}a_{i0} + G^{-1}a_{1t}t + G^{-1}Hx_{t-1} + G^{-1}\varepsilon_t \\ &= b_0 + b_1 t + F x_{t-1} + e_t, e_t \sim \mathscr{N}(0, \Sigma_e) \end{aligned} \tag{7}$$

To ensure stability for the equation above, the eigenvalues of F must lie inside the unit circle. But note that equation (7) is also a VAR(1) representation, with the error term e_t including a variance covariance matrix $\Sigma_e = G^{-1}\varepsilon_t G^{-1'}$ linking the contemporaneous relationship between countries. As so, it makes possible to use all the resources of the VAR methodology, including the identification restrictions, impulse response analyses, historical decomposition and the forecast error variance.

- BGSVAR: Bayesian estimation

One feature of the VAR is the high number of parameters estimates. An usual VAR contains $n + pn^2$ coefficients where n is the number of parameter and p the number of lags, showing how quickly the number of coefficients grows fast. For example, a VAR with only 2 lags and 4 variables involves 36 parameters, but this same VAR with 4 lags has incredible 68 parameters, which requires a much larger data set to estimate it. Even in the case of the GVAR approach which employs a smart strategy estimating less number of parameters, we still face the aforementioned problem of degrees of freedom. This issue becomes more challenging when we deal with macroeconomic series that, traditionally, do not have a wide span coverage.

The Bayesian VAR comes to deal with this challenging issue of degrees of freedom. In this subsection I strongly follow M. Feldkircher and Huber (2015) and Feldkircher et al. (2019) whose shows the application of the SSVS prior in the GVAR context. According to them, there are some interesting properties, that made the SSVS prior specification a good choice for the GVAR estimation. Hence, I will present some of this smart properties of the SSVS prior but recommend those papers if any doubt remains opened.

The SSVS is a hierarchical prior selection that applies shrinking on the parameters of the model. Formally, the SSVS prior takes into consideration the uncertainty about the variable choice which is very useful for this kind of estimation where it is allowed to vary specifications between countries[2]. Denoting the vector of coefficients for country i as $z_i = \{a'_{10}, a'_{1it}, vec\{\Lambda_{i0}\}, vec\{\Lambda_{i1}\}, vec\{\phi_i\}\}$ with $k_i = 2k_i + k_i(pk_i + qk_i^*)$ dimension, we have:

$$z_{ij}/\delta_{ij} \sim \mathscr{N}(0, \tau^2_{ij,0})\delta_{ij} + \mathscr{N}(0, \tau^2_{ij,1})(1-\delta_{ij}) \; for \; j = 1, ..., k_i \tag{8}$$

Where δ_{ij} is a random binary variable, assuming 1 if the a variable j is included in the model and 0 otherwise; $\tau^2_{ij,0}$ and $\tau^2_{ij,1}$ are the prior variances representing the spike and the slab

[2]As I will show in the next section, some countries VAR are different from each other

components, with $\tau^2_{ij,0} >> \tau^2_{ij,1}$ and $\tau^2_{ij,1}$ set close to 0. Those prior variances means that if there is a small coefficient in the model, the spikes component applies, pushing the posterior distributions towards zero. At the other hand, if the coefficient is higher, little shrink is used, letting the prior as non informative (the slab component). Hence, the posterior will be pushed towards zero or towards the value of the likelihood depending on the size of the coefficient.

The parameter δ_{ij} plays an important role in the prior selection because its value determines which prior variance of the Gaussian distribution in equation (8) is used. If δ_{ij} equals 1, the first term with the slab component is chosen and if δ_{ij} equals zero, the second term with the shrinking variance is adopted. Note that the parameter δ_{ij} should be estimated and following M. Feldkircher and Huber (2015) and Feldkircher et al. (2019) I assume a Bernoulli distribution prior with prior inclusion probability of 0.5 for all i and j. This means that every variable is equally likely to be in the country VAR model such that: $p_{ij} = 0.5 = p(\delta_{ij} = 1/z_{it})$. So, given the probability δ_{ij} =1, the posterior distribution $p(\delta_{ij} = 1/z_{it})$ can be written as:

$$p(\delta_{ij} = 1/z_{ij}) = \frac{\mathcal{N}(z_{ij} \mid 0, \tau^2_{ij,0})}{\mathcal{N}(z_{ij} \mid 0, \tau^2_{ij,0}) + \mathcal{N}(z_{ij} \mid 0, \tau^2_{ij,1})} \tag{9}$$

Equation (9) shows that we have a mixture of densities based in the centered value of z_{ij}. Supposing that z_{ij} is close to 0, the shrinking component would prevail and the posterior density will be close to 0. At the other hand, if z_{ij} is higher, then the slab prior variance would overcome and the posterior distribution will approximate to 1. One important feature of the SSVS is that no variable is excluded from the model even if a variable equals 0.

Regarding to the variance-covariance, I also follow a SSVS prior specification. But before introduce this prior, it is important to mention that I assume stochastic volatility for the variance-covariance in the estimation process. The stochastic volatility set up an auto regressive process for the log-volatilities of the error term, which might incorporate relevant characteristics of the series, like the periods of booms and busts and the volatility of the series[3]. This AR(1) process can be written as[4]:

$$s_{ij,t} = \mu_{ij} + \rho_{ij}(s_{ij,t-1} - \rho_{ij}) + \kappa_{ij,n} \tag{10}$$

where the s component comes from the diagonal element of the matrix $S_{it} = diag(\varepsilon^{s_{i1,t}}, ..., \varepsilon^{s_{ik,t}})$, μ_{ij} is the unconditional mean, ρ_{ij} represents the inertia parameter and $\kappa_{ij,n}$ is a white noise disturbance with variance ζ^2_{ij}. The SSVS prior specification for the variance-covariance have some parameters that can made the stochastic volatility given in Equation (10) works like an homoscedastic case or more volatile one. To see this, let SSVS prior for the variance-covariance been represented by:

[3]The stochastic volatility improves the fit of the model and take into account the volatility of the series, controlling for heterocedasticity problems.

[4]Remember that according to Equation (1), the error term can be decomposed in the following variance-covariance matrix: $\Sigma_{it} = V_i S_{it} V_i^{'}$

$$v_{ij,n}/\kappa_{ij,n} \sim \mathcal{N}(0,\xi^2_{ij,n0})\kappa_{ij,n} + \mathcal{N}(0,\xi^2_{ij,n1})(1-\kappa_{ij,n}) \quad (11)$$

where $v_{ij,n}$ represents the elements of V, $\xi^2_{ij,n0}$ and $\xi^2_{ij,n1}$ are prior variances that denotes the shrink and slab components for the variance-covariance in the such way: $\xi^2_{ij,n0} >> \xi^2_{ij,n1}$, with $\xi^2_{ij,n1}$ close to 0. The $\kappa_{ij,n}$ is a random binary variable, with a Bernoulli distribution. As it has been done with the prior inclusion probability for the parameters, it is assumed that $\kappa_{ij,n}$ has a prior inclusion probability set equally, or in other words: $p(\kappa_{ij,n} = 1) = 0.5$. The ζ^2_{ij} captures how the shrinking and slab components act. If we set the ζ^2_{ij} as zero, for example, we will have a stable s, which means that we approximate to a homocedasticity case, where the shrinking component applies.

For the estimation process I consider the following hyperparameters values: $\tau^2_{ij,1} = 0.1\hat{\sigma}^2_{ij}$ and $\tau^2_{ij,0} = 3\hat{\sigma}^2_{ij}$ where σ^2_{ij} is the OLS variance of the z_i along with $\xi^2_{ij,n0} = 0.1$ and $\xi^2_{ij,n1} = 7$ for the prior values for the variance-covariance. Additionally, with respect to the prior distributions for the stochastic volatility I assume a Gamma prior on the $\zeta^2_{ij} \sim \mathcal{G}(1/2,1/2)$; a normally distribution prior for the $v_{ij,n} \sim \mathcal{N}(0,10^2)$ and a Beta distribution for the ρ_{ij}. All of these hyperparameters values as the distributions choices follow closely Feldkircher et al. (2019).

I used the R library BGVAR for estimate the BGSVAR. This package allows us to estimate the BGSVAR carrying out the MCMC methods, with a wide range of prior distributions and structural identification. For more technical details as for example the algorithm that is used to do the MCMC and the posterior simulation see Böck et al. (2020)[5]. In the estimation process I considerate a lag 1 BGSVAR with 60000 draws and 30000 burn-ins. Its descritive statistics is shown in Appendix A.

- BGSVAR: sign restriction approach

I will carry out the sign and zero restriction as a structural identification approach. The sign and zero restrictions was first showed by Uhlig (2005). This kind of restrictions was developed to avoid strong contemporaneous restrictions that usually comes with the Cholesky decomposition. The sign restrictions employs an agnostic identification scheme based on solid assumption of what is going on with the data or in how this data usually responds to a shock. Uhlig (2017) justify his method giving interesting examples of how we can apply sign restriction based on these good premises. Regarding Uhlig (2017) lessons, it is possible, in the context of the exchange rate pass-through, insert a sign restriction taking into considerations some assumptions. For example, it is expected that after an exchange rate depreciation, the consumer prices do not decreases and the risk premium increases at same time. Hence, we might applied this sign restriction if it is supported by theory or empirical evidence

[5]The BGVAR package includes a lot of technical details as a brief explanation of the stochastic volatility used, the efficient algorithm for large VAR estimation and the SSVS prior distribution algorithm in the GVAR context applied.

In the context of the GVAR this strategy opens a wide variety of restrictions due to the fact that we deal with endogenous and weak exogenous variables. However, the GVAR approach allows only local identification schemes, closing the opportunity to restrict weak exogenous variables. This characteristic is easy to understand and do not erase the GVAR appealing because would be very difficult to defend an identification scheme for foreign variables. The GVAR has some another interesting features in terms of identification strategy: (i) gives the possibility to shock the same variable of each country, at the same time, mimicking what should be a regional/global shock. (ii) it permits the analysis of the spillover effect even though it is not possible to impose any restriction in the weak exogenous variables.

Regarding the estimation process, the sign restriction uses the rotation matrix algorithm proposed by Arias et al. (2019). It should be pointed out that, before we impose the sign restriction, the model is structural identified (Cholesky). So, indexing a country i by $i = 0$ we can introduce a $k_0 \times k_0$ dimension block diagonal rotation matrix $R_{0,t}$ with $R_{0,t}R_{0,t}^{'} = I_{k0}$ in the following structural equation:

$$\tilde{Q}_{00,t}x_{it} = \tilde{a}_{i0,t} + \tilde{at}_{i0,t} + \tilde{\phi}_{i1,t}x_{it-1} + \tilde{\Lambda}_{i0,t}x_{it}^{*} + \tilde{\Lambda}_{i1,t}x_{it-1}^{*} + \tilde{R}_{i0,t}\varepsilon_{it} \qquad (12)$$

where $\tilde{Q}_{00,i} = R_{0,t}Q_{00,t}$ with $Q_{00,t}$ representing the contemporaneous relationship between the countries as long as the model is already identified, $\tilde{a}_{i0,t} = R_{0,t}a_{i0,t}$, $\tilde{at}_{i0,t} = R_{0,t}at_{i0,t}$, $\tilde{\phi}_{i1,t} = R_{0,t}\phi_{i1,t}$, $\tilde{\Lambda}_{i0,t} = R_{0,t}\Lambda_{i0,t}$ and $\tilde{\Lambda}_{i1,t} = R_{0,t}\Lambda_{i1,t}$. The matrix $R_{0,t}$ is orthogonal only to the country $i = 0$ which represents the local identify assumption, with the remaining countries having a general identification scheme. It is important to mention that the rotation matrix is time varying and should be simulated in each point of time. Notice that the equation (12) is the equation (1) with the matrix R applied to it and considering that is already identified.

Finally, two points should be mentioned in the sign restriction approach: the restrictions can be applied contemporaneously and for more periods (longer horizons). Indeed, increasing the number of restriction decreases the uncertainty of the model but it makes harder to find a rotation matrix. So it is possible to not find any rotation matrix if the model is very restricted.

2.1 Data sample

We followed two directives for the data sample chose: the first one and most important is the need of a floating exchange rate regime. As we are evaluating the pass-through, the exchange rate must have some variability even though it is a dirty exchange rate float. The second directive is the availability of the data. The countries analysed should have at least the GDP, the inflation rate, the nominal exchange rate and the interest rate at a quarterly basis in a wider span

.

In line with these directives we cover five Latin America countries for the period between 2002Q1 and 2019Q4: Brazil, Chile, Colombia, Mexico and Peru. Due to the weighted trade flows in the BGVAR approach, four big economies (China, Euro-Zone, Japan and the USA) are added in the estimation, to mimic better the real trade flows, otherwise it will settle much higher weight for the commerce between the Latin countries[6]. To construct the matrix of trade flows, we have used the average of 2017,2018 and 2019 bilateral trade flows. For the Latin countries VAR estimation we have the following indicators:

$$x_{it} = (y_{it}, dp_{it}, ner_{it}, embi_{it}, ir_{it})' \tag{13}$$

where: y is the is the output gap calculated by the HP filter with λ set at 1600, dp is the quarterly inflation rate, *ner* is the nominal exchange rate calculated as the domestic currency per US dollar, *EMBI* is a Sovereign Risk Premium measured by the quarter mean of the Emerging Market Bond Index and *IR* is the annualized interest rate[7]. CPI NER and Sovereign Risk Premium are in log differences and the interest rate is annualized at level [8].

we have assumed a different variables set for the big economies, incorporating some particularities of these countries in the world economy. For the USA and China, for example, we include the commodities index due to the relevance of those economies to determine its prices by their demand movements. At same time we add the VIX for the Europe and the USA as a source of volatility shock. The country-specific VAR estimation variables can be seen above:

$$\begin{aligned} USA: x_t &= (y_t, dp_t, fuel_t, agri_t, met_t, dyx_t, vix_t, ir_t)' \\ Euro: x_t &= (y_t, dp_t, fuel_t, ner_t, vix_t, ir_t)' \\ China: x_t &= (y_t, dp_t, fuel_t, agri_t, met_t, ner_t, ir_t)' \\ Japan: x_t &= (y_t, dp_t, ner_t, ir_t)' \end{aligned} \tag{14}$$

The commodity index is separated by its class. The $fuel$, *agri* and *met* denotes the log differences of the Fuel, Agriculture and Metal prices indexes respectively[9]. we have separated the commodities by its class for two main reasons: (1) to avoid an ERPT improper analysis since the energy prices might been controlled in some countries. (2) to enable a richest analysis

[6] As mentioned before, the trade flows matrix is built to sum up 1 and this done by normalizing the matrix of the countries available in the estimation. If we add relevant countries in terms of trade flows to the Latin economies, the shocks spillover between them is more approximated to the real trade flow. For this reason we also have added Argentina in the estimation although due to data problems we do not show the result

[7] One should note that including the long term interest rate would improve our estimation. However for most of the Latin countries the long term interest rate is only available after 2005 and 2006

[8] The original series of GDP and CPI are seasonally adjusted and comes from Mohaddes and Raissi (2020). The original data-set uses the real exchange rate (*rer*), so we compute the *ner* as: $ner = dp * rer$. The *ner* is the average in the quarter. The interest rates is from Mohaddes and Raissi (2020) but it has been transformed in an annualized basis series. For Colombia the data comes from the official national bureau statistics and the Colombia's Central Bank.

[9] The commodities indexes are from the Primary Commodity Price System of the IMF. The Agriculture index comprehends Agriculture Price Index, including Food and Beverages and Agriculture Raw Materials Price Indices. The Metal index is the Base Metals Price Index, including Aluminum, Cobalt, Copper, Iron Ore, Lead, Molybdenum, Nickel, Tin, Uranium and Zinc Price Indices. The fuel index includes Crude oil (petroleum), Natural Gas, Coal Price and Propane Indices.

considering that Chile, Peru (metal exporters) and Brazil (metal and agriculture exporters) are relevant exporters on this market. The *dyx* is the trade weighted dollar index. Considering the commodities index as endogenous for the USA and China economies is straightforward due to the relevance of those economies to determine the price of these products.

The dynamics of the Latin countries can be modelled by a VARX(p,q) with k endogenous variables defined in (13) and j weak exogenous variables coming from (14) and the others economies in (13). Hence, for each Latin country i, we have:

$$x_{it} = \sum_{s=1}^{p} \phi_{is} x_{it-s} + \sum_{r=0}^{q} \Lambda_{ir} x^*_{it-r} + \varepsilon_{it} \tag{15}$$

where x_{it} is a $(k_i \times 1)$ vector of endogenous variables, ϕ_{is} is a $(k_i \times k_i)$ diagonal coefficient matrix of each endogenous variables, Λ_{ir} is the matrix $(k_i^* \times k_i^*)$ associated to the weak exogenous variables x^*_{it} and ε_{it} is the error term with zero mean and time- varying variance-covariance matrix Σ_{it}.

The weak exogenous variables x^* are built as a weighted mean of others economies endogenous variables:

$$x^*_{it} = \sum_{j=0}^{N} \omega_{ij} x_{jt} \tag{16}$$

with ω_{ij} representing the bilateral trade flow between countries i and j. In the trade flow matrix, we have $\omega_{ij} = 0$ for $i = j$ and $\sum_{j=0}^{N} \omega_{ij} = 1$. This assumption considers that a country shock might not have a great impact into other country unless they have a relevant commerce between them as for example: Brazil/Japan, USA/Mexico, China/Chile and so on. Following the GVAR approach, we let the nominal exchange rate as the only variable not included in x^*[10]. The weighted trade flows used in the estimation is shown in Appendix A.

3 Identification

Dealing with VAR identification is challenging. Since Sims (1980) presented the VAR methodology as an approach to avoid imposing ad hoc restrictions, several VAR's structural identifications strategies have been proposed. Most of these identifications schemes has been scrutinized since some of them relies on strong assumptions. These assumptions stems from the fact that we should be confident if these restrictions comes from exactly the shock that we are aiming to identify and not due to a linear combination of others shocks.

Taking this under consideration, Uhlig (2005) proposed a new identification strategy, with a minimalist approach, identifying structural shocks through sign restrictions. The idea is to impose a minimal restriction's set to avoid controversial identifications. For example, many

[10]The foreign nominal exchange rate is not included in the weak exogenous variables set because it will appear as an effective exchange rate, disturbing the analysis of the ERPT.

economists agree that after a positive monetary shock, the price level usually goes down and the interest rate rises. However, the GDP response is not so clear, particularly about the time horizon that is hit by the monetary policy shock. Some researchers argue that it takes time to GDP be affected and other ones support the notion that there is a small contemporaneous effect (Uhlig (2017), Forbes et al. (2018)). Our strategy is to not enter in this kind of identification discussion because we could expend many pages discoursing about it and there are other identification polemical examples. So, we will apply restrictions which are less controversial, covering the Uhlig (2017) idea: "if you know it, impose it; otherwise not". Following this line, if the literature has no closed opinion about some restriction like the contemporaneously GDP reaction after a monetary policy shock we will let the variable unrestricted.

An important feature of the GVAR models is that we can either deal with individual countries VARs and with the global representation of the model. Hence, it is possible to figure out how a single country responds to a domestic shock or how it responds to a shock that comes from abroad. This external shock might come from an important trade partnership or from a group of countries (global shock). Indeed, as the model is locally identified, this shock can be at the same time internal and external which means that the same event hit all the economies. Considering this GVAR characteristic, we will analyse three sources of shocks for the Latin American countries: (i) a domestic shock of each individual Latin America country, (ii) a regional shock, a shock that hits all the Latin American countries at same time and (iii) a global shock, an economic shock that spreads for the whole world.

For the domestic shock, we contemplate the usual shocks that have been applied in the VAR literature such as: a monetary policy shock and a demand shock. The identification of those shocks have been exhaustive analysed before and we will just follow what have been applied. Additionally, we consider an EMBI shock representing a risk premium shock. The identification of this shock is straightforward: the exchange rate depreciates after a positive risk premium shock which rises the inflation rate and the central bank reacts to this environment increasing the interest rate. The risk premium shock may come from several sources that might affect the ability of a country meet its external debt obligations, like the fiscal balance, business cycle expectation, risk aversion and terms of trade. In spite of all, an unidentified exchange rate shock is also considerate as a benchmark. [11]

Regarding the regional shock, we contemplate a risk premium and a monetary policy shocks for the Latin America region. we identify them as a shock hitting all the Latin American economies at the same time allowing the spillover effect between the countries. It's worth noting that this kind of shock has been chosen because they are relative common in the region's history and uses non polemical identification restrictions. Finally, a global shock is analysed. we consider 2 types of shocks: an uncertainty shock, where the risk aversion goes up and a demand commodities shock. An important point should be highlighted because the identification of the commodities shock is non trivial as long as this kind of shock is usually followed by an

[11]It is called an unidentified shock because its source has not been identified.

economic expansion as stressed by Baumeister and Hamilton (2019). So, even if we call it as a commodities shock, this shock can be seen as a demand shock as well.

In order to summarize the shocks identification, Table 3.1 presents how the sign restrictions are applied in each shock mentioned in this section:

Table 3.1 - Identification restrictions - Latin Countries[1,2,3]

	Output Gap (Demand Shock)	CPI	Exchange rate Shock	Risk Premium Shock	Interest rate Shock	Risk Premium* Shock	Interest rate* Shock	VIX* Shock	Oil price index* Shock
Output Gap	$>^{2}$		0	0	0	0	0		
CPI	$>^{2}$		$>^{2}$	$>^{2}$	$<^{2}$	$>^{2}$	$<^{2}$		
Exchange rate	*		$>^{2}$	$>^{2}$	$<^{2}$	$>^{2}$	$<^{2}$		
Risk Premium	*		$>^{2}$	$>^{2}$	*	$>^{2}$	*		
Interest rate	0		0	0	$>^{2}$	0	$>^{2}$		
Output Gap*						0	0	*	$>^{2}$
CPI*						$>^{2}$	$<^{2}$	*	*
Risk Premium*						$>^{2}$	$<^{2}$	*	*
VIX*								$>^{2}$	*
Oil price index*								*	$>^{2}$
Agriculture price index*								*	$>^{2}$
Metals price index*								*	$>^{2}$
Interest rate*						0	$>^{2}$	*	*

1/ Variables bellow the dot line represents variables that are treated as weak exogeneous (superscript *) for the Latin countries.

2/ The restrictions can be applied only for existing variables for a country. So if I shock the Oil Price index, for example, the restrictions are avaiable only for the countries where the Oil Price is assumed as endogeneous in the estimation.

3/ The signs >, < and 0 are the sign and zero restrictions applied in the structural identification scheme. The superscript above the sign denotes the periods which the restrictions remain active. Asteriscs inside the matrix represents variables not restricted. Blanck spaces are variables not restricted due to the impossibility of doing that (remember that the shocks are locally identified).

Note that, according to Table 3.1, we consider each sign restriction lasting for 2 periods. This assumption is usually made with sign restrictions approach as can be seen in Uhlig (2005, 2017) , Forbes et al. (2018), Feldkircher et al. (2019) among others. However, as a robustness exercise we also consider this sign restriction remaining only for the period when the shock occurs and there is no change in the results. Lastly, but no less important, for the Regional and Global shocks the sign restriction should hold for at least 75% of the draws[12].

4 Results

In this section the results of the BGSVAR are presented. we highlighted the impulse response functions of the shocks identified in the last section, and the values found for the ERPT. These tools enable us to answer how the exchange rate pass-through behave after it is hit by the shocks. This analysis is provocative because it considers other important variables that influence the magnitude of the ERPT. Additionally, an important point should be highlighted when we investigate an ERPT with a VAR: there are more variables that affect the dynamics of the inflation rate in the subsequent periods after the shock and is unfeasible to separate the CPI response considering only the exchange rate movement. Thus, the ERPT is defined as the ratio of the inflation response in all periods after the exchange rate movement in time 0. Mathematically we have: $\frac{dp_{0,t+i}}{ner_{0,t}}$ where dp is the change of prices from a period t to i and ner is

[12] we tried to let 100% of the draws holding for Global shocks but it is not possible to find a rotation matrix for some of them.

the change of the nominal exchange rate in time 0. This definition is also considered in some related literature as for example in An and Wang (2011), Forbes et al. (2020).

4.1 Impulse Response Functions

We divide the impulse response function (IRF) by its source. First we show the response function of the domestic shocks, followed by the regional shock and finally by the global ones[13]. In the following IRF plots the solid line represents the median of the posterior and the dark gray (50%) and light gray (68%) are the credible intervals of the successful rotation matrices found in each of the shocks estimated.

- Individual countries shocks:

The first shock analysed is the exchange rate shock. According to figure 4.1 it can be seen that following a shock in the nominal exchange rate the inflation rises in all countries. This upward pressure on the CPI remains for at least 2 quarters, with Peru having the more persistent response. The output reacts in different manner depending on the country analyzed with Brazil, Colombia and Peru experiencing a recession after the exchange rate depreciation and other like Chile having a boom in its economy. This result is in line with An and Wang (2011) who do not find a regular output response for countries after an exchange rate depreciation. These different output reaction might come from several factors as for example the dollar liabilities in those countries. As stressed by Kearns and Patel (2016) we have a general idea maybe coming from the trade channel view that an exchange rate depreciation might be expansionist. But the financial channel also plays an important role, tightening the domestic financial conditions, specially if the country have a large stock of foreign currency borrowing. The prevalence of one of these two channels may explain the different output response. Note that as higher is the inflation rate more intense is the reaction of the monetary policy, rising the interest rate and contributing to slowdown the output gap. The output gap becomes negative maybe because of the rise of the interest rate and not due to the depreciation of the exchange rate. However, as we have not identified the source of the exchange rate depreciation, it is difficult to infer what should be the output response.

It is worth noting that this is a kind of shock that is difficult to explain as long as the exchange rate movements are consequences of what happens in the economy. In such manner it is complicated to analyse the exchange rate shock as an event that appears in a exogenous way without an identified source. Nevertheless, we consider this shock because it is relevant to show how the magnitude of the ERPT varies over other identified shocks.

According to Figure 4.2, a risk premium shock is followed contemporaneously by an exchange rate depreciation. This exchange rate movement leads to higher inflation with Brazil

[13] As we are dealing with shocks in 8 countries, we consider the following shock size for each of the IRF: 0.1 for the exchange rate shock, a 0.2 for the risk premium shock, a 100 basis point for the monetary policy shock, a 0.02 for the demand shock, 1 for the VIX and 0.2 for the commodities indexes.

and Colombia having a higher inflation rate in the subsequent quarters after the depreciation. In all countries the Central Bank rises its interest rate to combat the inflationary upward pressure. This Central Bank's behavior may contribute to decrease the output gap in the following quarters. In addition it is expected that the output gap should not get positive after a risk premium shock because this is a kind of shock which probably comes from some domestic or global stressful event. Thus, even if the Central Bank do not rise the interest rate, the GDP may decrease. Chile and Mexico are the countries which we observe a rise in the GDP following the risk premium shock, a result that is, somewhat, puzzling.

Next we consider a 100 basis point interest rate shock in Figure 4.3. The exchange rate appreciates contemporaneously with CPI tracking this movement. Remember that in the identification strategy we let the CPI be impacted simultaneously by the monetary policy shock. This might be controversial but if we have assumed that the ERPT can occur contemporaneously, any movement in the exchange rate should impact the price level at the same time. Note that in all countries there is no price puzzle phenomenon. As seen in the risk premium shock, Chile and Peru have the higher response of the inflation rate.

The demand shock is analysed in Figure 4.4. Regarding the inflation rate this is the shock in which the CPI gets higher. This behavior of inflation increasing might occur even if the exchange rate pass-through remains stable since it is a characteristic of this kind of shock, i.e: output gap and inflation rate moving in the same direction. However, the exchange rate also depreciates following this shock which means that we might have a strong ERPT. As either the GDP growth is strong and the price level is increasing at the time when the exchange rate depreciates it creates a favorable scenario to have a higher degree of ERPT.

- Regional shocks:

The regional risk premium shock is an event that hits all the Latin American countries at the same time. We have seen a similar result in the domestic counterpart shock, with the GDP slowing down, the exchange rate depreciating, CPI rising in the first quarters and the Central Bank's increasing the interest rate in order to control this inflationary pressure. However, in the regional shock it is possible to see a more complete picture of what happens when this kind of shocks occurs. Regarding the EMBI, this is a variable that usually moves together across the countries and considering this feature with the spillover effect is essential, particularly for some countries that have big trade partnership in the region. According to Figure 4.6, it is interesting to note that in some countries as in Brazil for example, the output grows in the first quarter after the shock and only after 2 quarters it begins to enter in the negative part. This polemical dynamic might be due to the forward characteristic of the risk premium, showing that there is something cloudy in the horizon but it will take time to hit the real economy. A possible precedent is a rise in the government expending, enhancing the output in the short run and worsen the fiscal balance for the years coming. But as we are dealing with a shock that probably comes from abroad, this explanation is not complete because a worsen in the

Brazil's fiscal balance will not erase the risk premium of all Latin America. The most suitable explanation is a worsen of the fiscal balance but as consequence of the risk premium shock that comes from abroad. Thus, the government reacts to this challenging scenario and the output remains stable in the first quarters after the risk premium shock. This output (positive) reaction can be seen for all Latin American countries but Colombia.

Next we consider a jointly monetary policy shock in Figure 4.6, called regional monetary policy shock. At the same time, all Latin American countries rise its interest rate. As consequence the exchange rate appreciates and the inflation rate goes down in all countries. This result is quite similar of what we have seen in the domestic monetary policy shock. A possible reason for this similar result is due to the economic activity channel. Note that the output gap remains quite stable after the interest rate rise, what makes the spillover effect by the economic foreign activity channel less important.

- Global shocks:

The global shock is an event that comes from the biggest economies in the world and have the potential to spread through the world. The first scenario analysed is when an uncertainty shock hits the US and European economies at the same time. I proxy the uncertainty with the VIX term, and consider this variable is shocked at time 0, letting the other variables in the VAR model unrestricted. Remember that only US and Europe VARs include the VIX in their VAR specification, being two important Latin America countries trade partnership. According to Figure 4.7 we see an instantaneous decrease in the output gap in all countries and the risk premium increasing in time 0, with a depreciation following this EMBI movement. The inflation rate in Brazil, Colombia and Mexico goes up in the first quarters after the uncertainty shock but in Chile and Peru the price level decreases strongly. The output gap path may determine the response of the inflation rate since an economy in recession, usually, does not have demand pressures that could force the CPI to higher levels. In this case, the price level decreases, although there are other variables making inflationary pressure as a depreciation of the exchange rate, for example. To summarize, it look likes that in the uncertainty shock the strong output response is responsible of the CPI path.

The commodities/demand shock is one of the most interesting shocks analysed in this paper since it includes some important characteristic for the Latin America countries. First of all, remember that I have identified the global commodities shock as a shock with positive sign restriction for the output gap and the commodities indexes. Then, not only the foreign demand factor would hit the Latin American countries but also the higher price of those goods. As some of those countries are huge commodities exporters the rise of these prices affect their trade balances, the terms of trade, the exchange rate, the risk premium and the output gap.

According to Figure 4.8, a global demand/commodities shock decreases the risk premium of all countries with an appreciation of the exchange rate following this movement. The output gap is boomed contemporaneously what shows the relevance of the terms of trade to the economic activity. The inflation rate of Colombia and Mexico remains quietly stable although the strong GDP growth in these countries. At the other hand Chile and Peru experience an increase in the price level, maybe because their GDP growth is stronger than the other country's GDP. In all countries we observe a decrease of the risk premium with an appreciation of the exchange rate in time 0.

Figure 4.1 - Nominal exchange rate shock - Latin countries

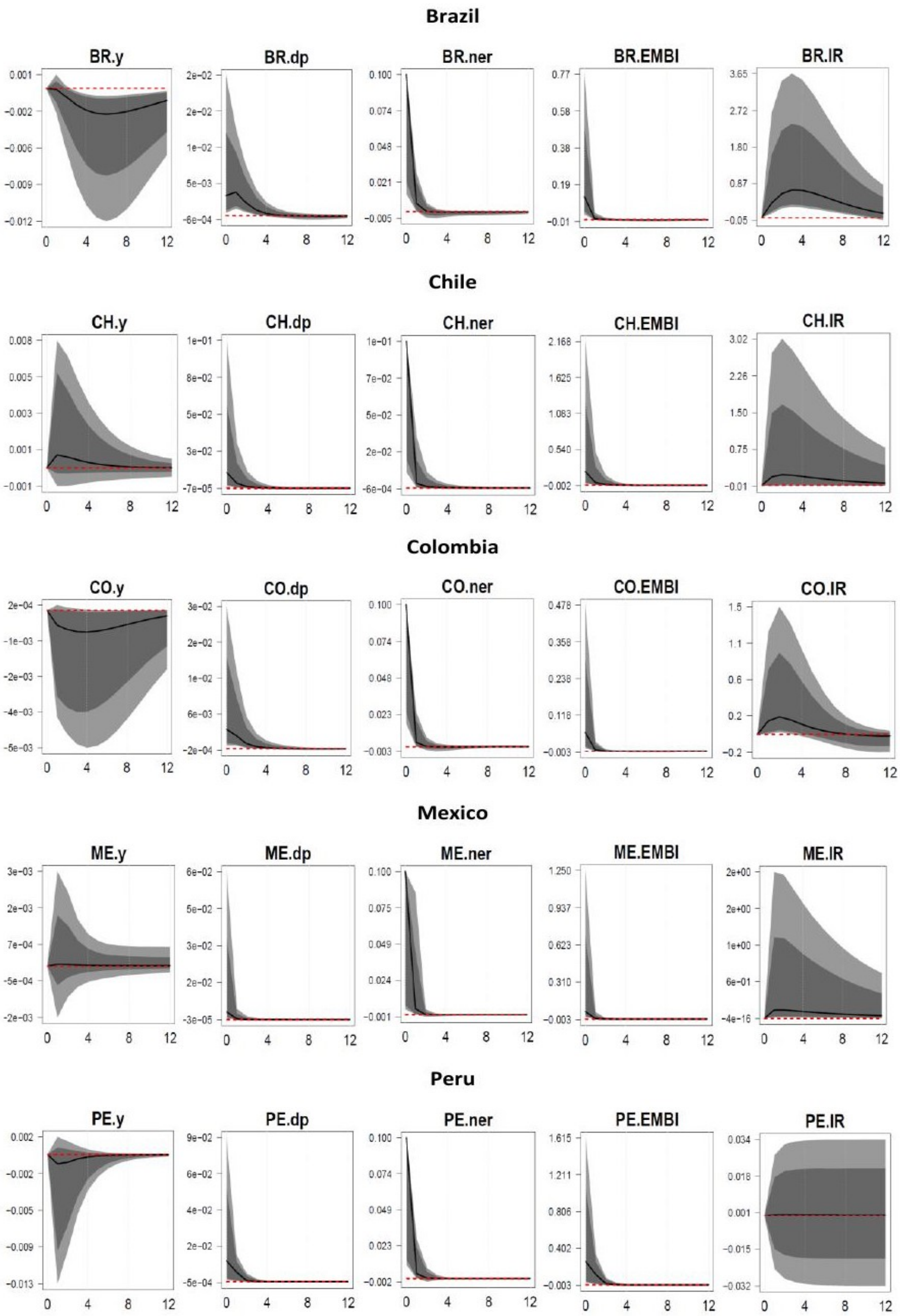


Figure 4.2 - Risk Premium shock - Latin countries

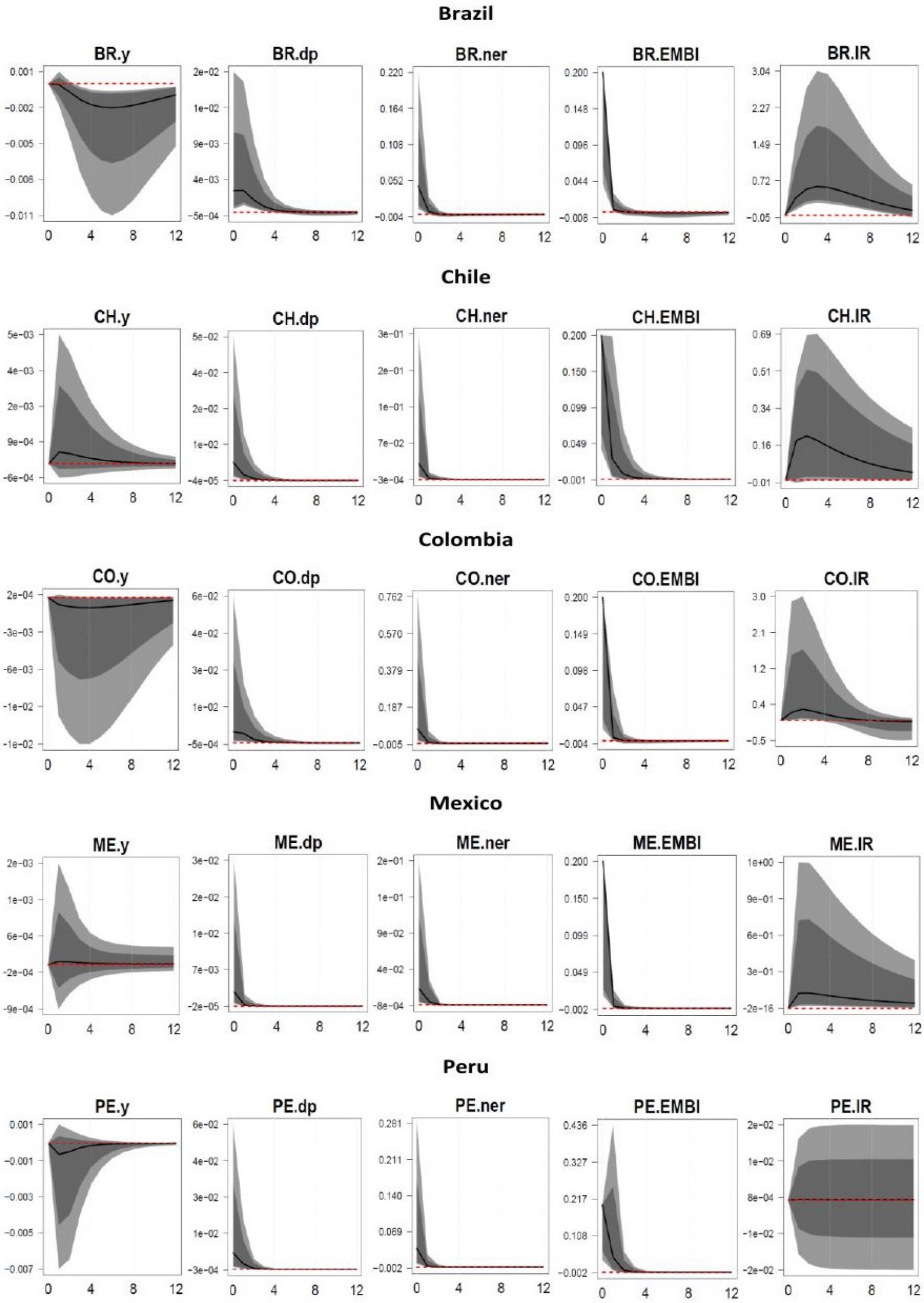


Figure 4.3 - Monetary Policy shock - Latin countries

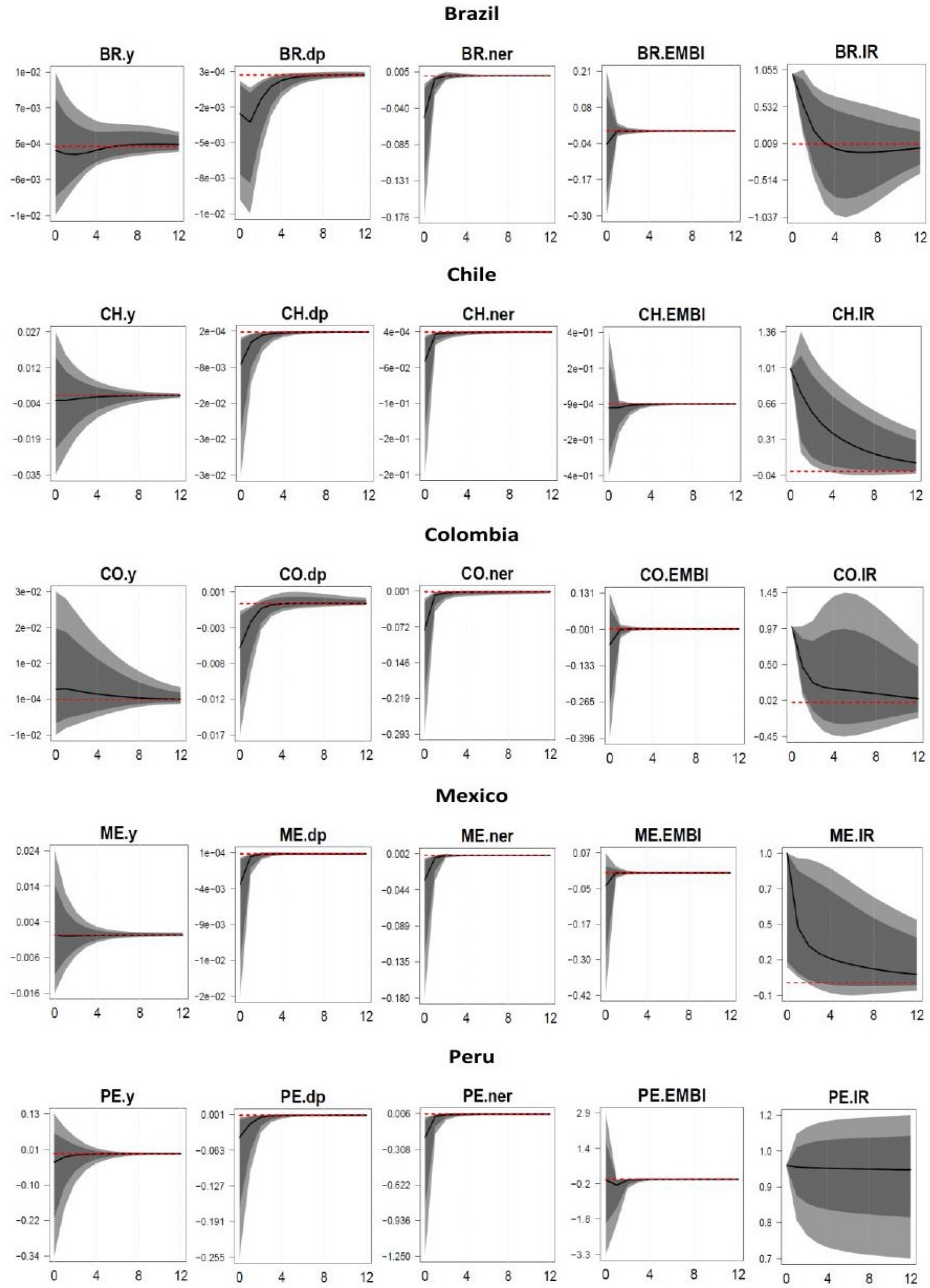


Figure 4.4 - Demand shock - Latin countries

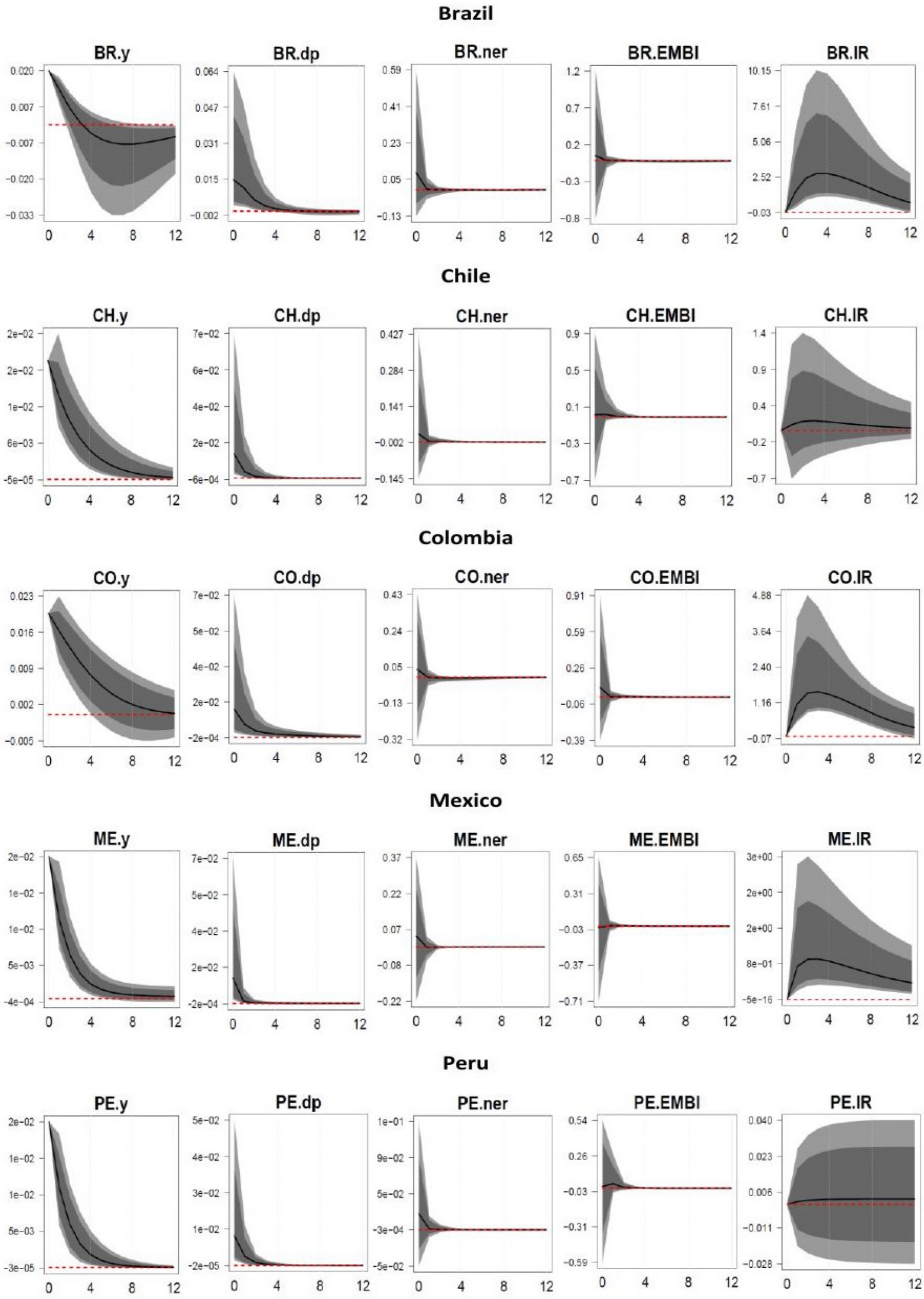


Figure 4.5 - Regional Risk Premium shock - Latin Countries

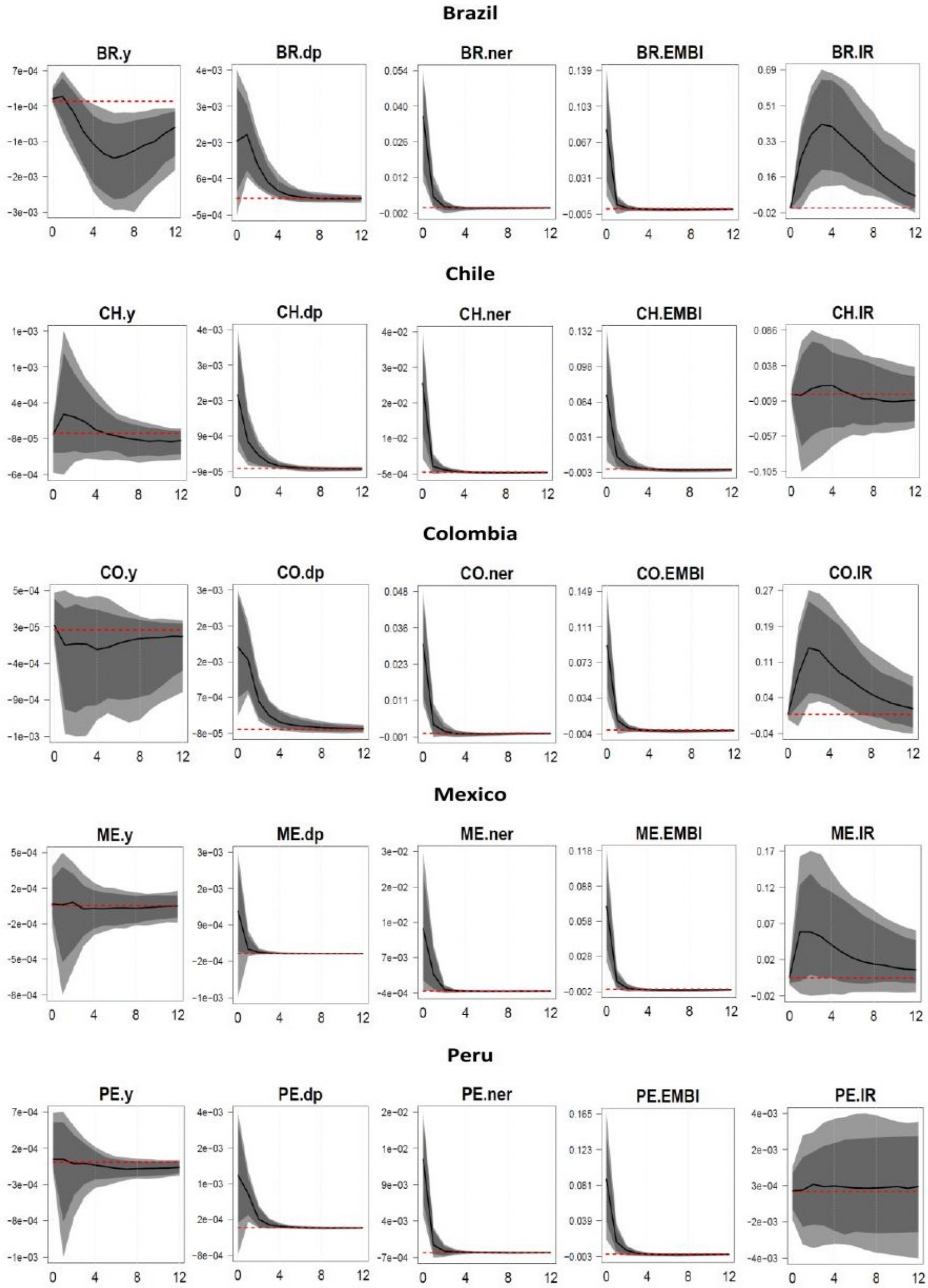


Figure 4.6 - Regional Interest rate shock - Latin Countries

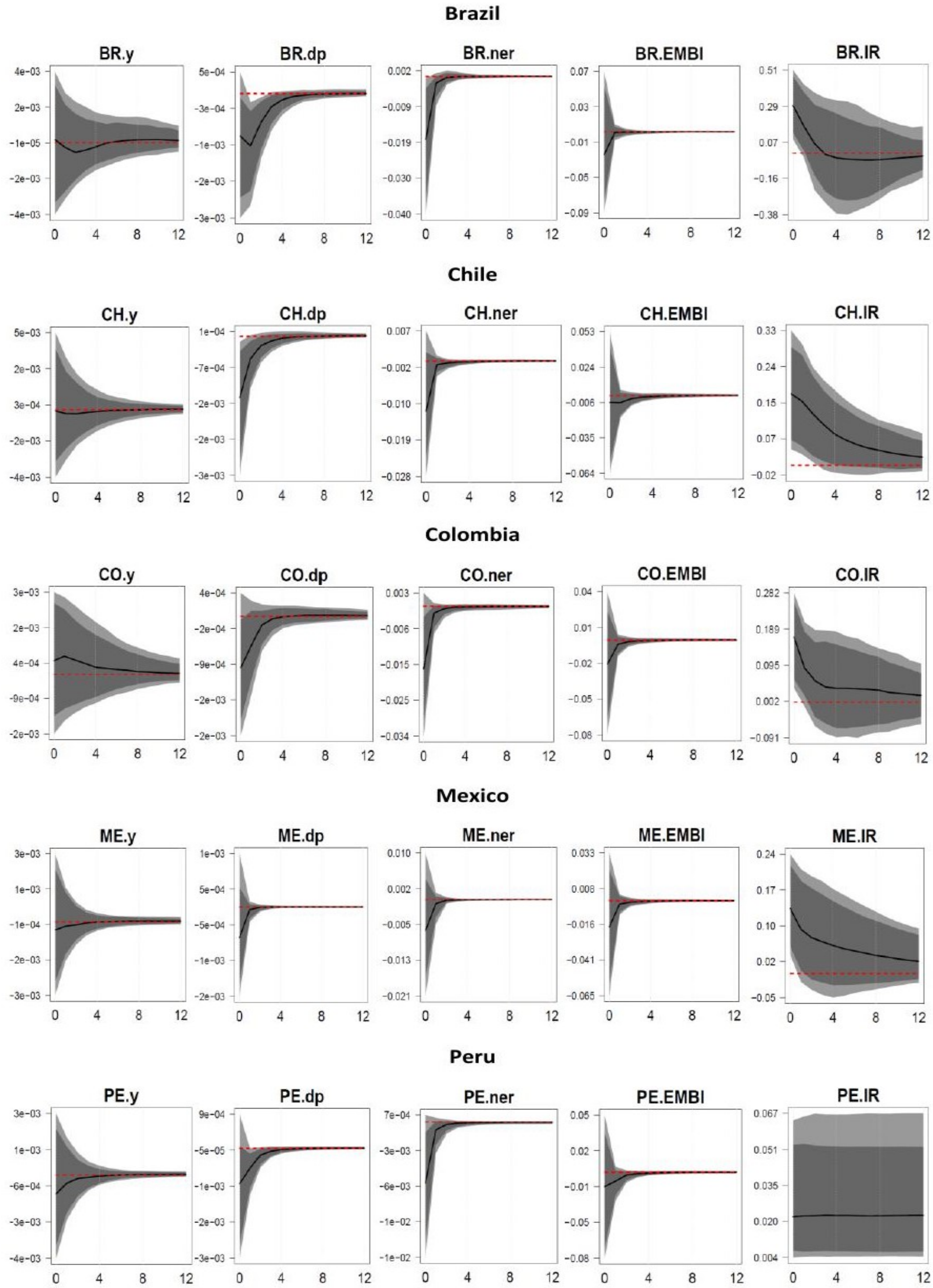


Figure 4.7 - Uncertainty shock - Latin Countries

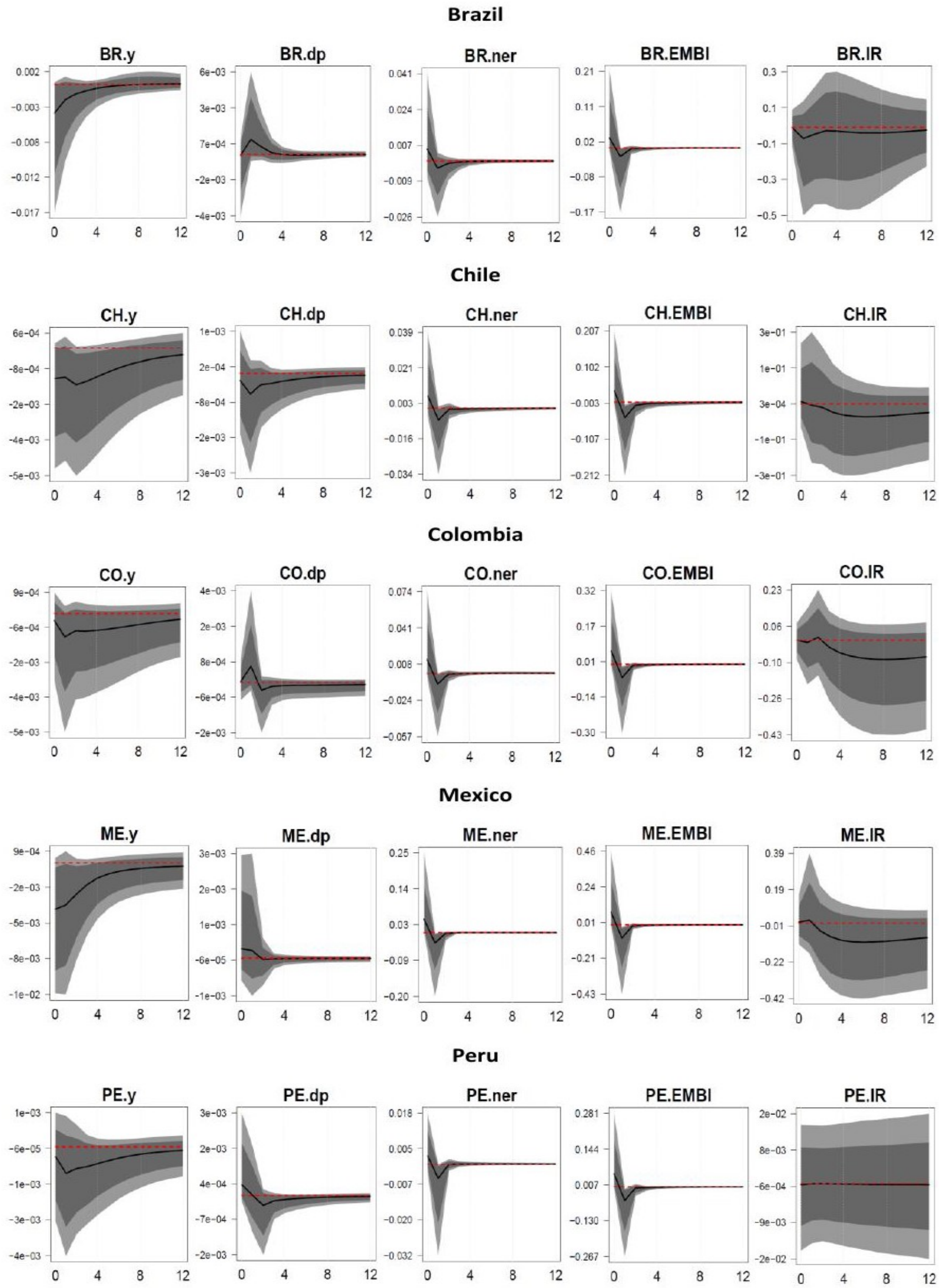
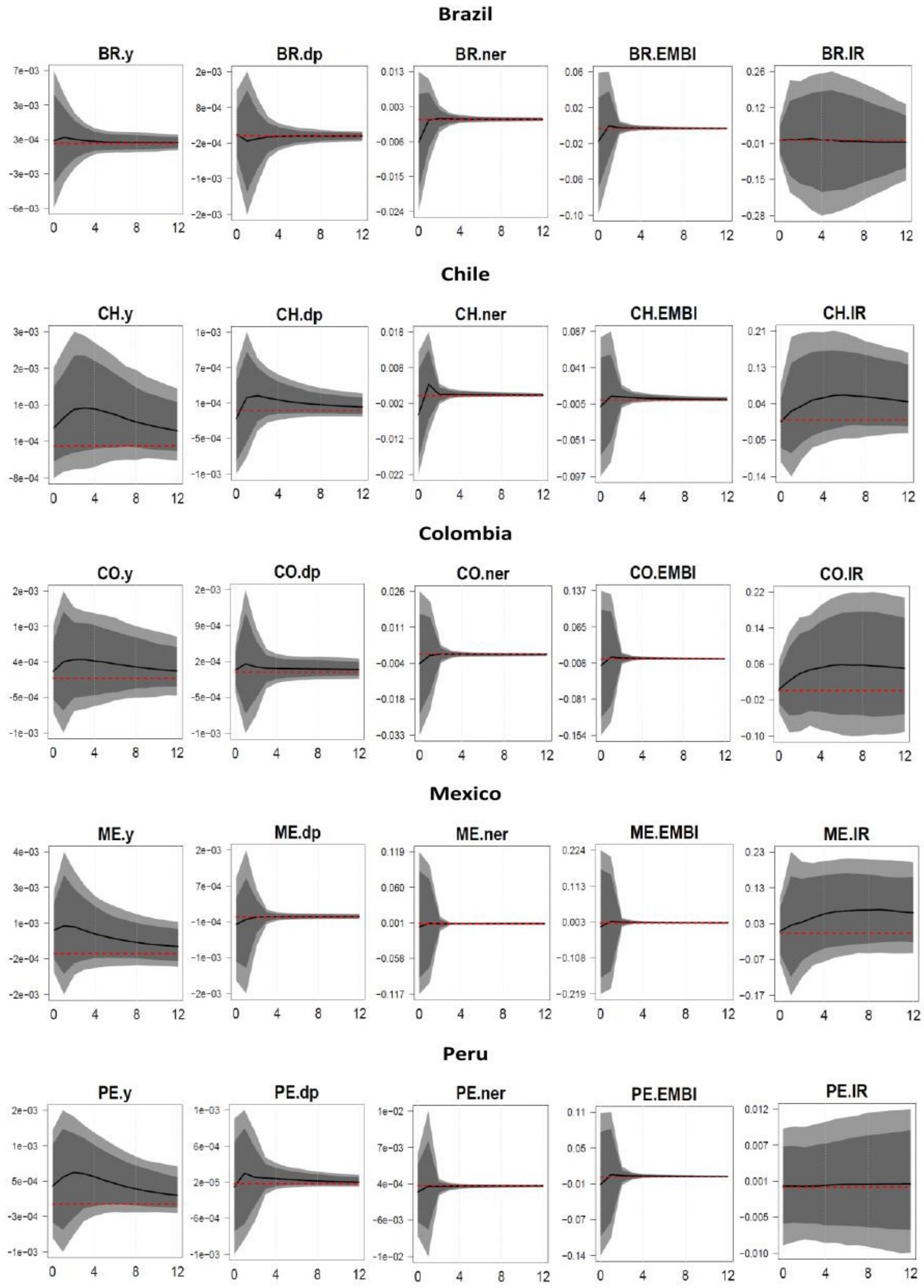


Figure 4.8 - Global commodities demand shock - Latin Countries



4.2 Exchange rate pass-through

In this subsection we investigate the median response of the ERPT. It is calculated by the ratio $\frac{dp_{0,t+i}}{ner_{0,t}}$ and give us a number of how different is the pass-through for each of the shocks analysed in the IRF. According to Table 4.1, the (unidentified) exchange rate shock is the event that has the lower ERPT in all countries. This result highlights the ERPT coming from a simple exchange rate shock might give us an incomplete picture of the dynamics of the economy. An interesting point is the relevance of identify the shock to determine the magnitude of the ERPT is the risk premium shock compared with the exchange rate one. They have the same sign restriction even-though the risk premium ERPT degree is much higher for all countries, with some like Brazil having a double degree of ERPT in time 0. Regarding the monetary policy shock, it is similar in magnitude of the ERPT with the risk premium shock.

The domestic demand shock exhibits the highest magnitude of the ERPT. This result might comes from the fact that this shock covers some economic features which are important to determine the magnitude of the exchange rate pass-through. As mentioned before the degree of the ERPT is higher when the average inflation is higher and the economic activity is booming and that's exactly what we have in the domestic demand shock. So, when the exchange rate moves (depreciates) it encounters a desirable scenario to pass-through to the consumer price level. It is worth noting that even-though this result contrast with Forbes (2018, 2020) it is not directly comparable because they found a low degree of the ERPT for an appreciation case and in all of our demand shocks there is a depreciation of the exchange rate. Indeed, the reason claimed for this low ERPT in Forbes (2018, 2020) might justify the same result find here for an depreciation event: if the price setters have no incentive to decrease prices when they faces a strong demand growth, they also have more incentives to pass-through to its prices any increase in its costs; including a cost increasing that comes from an exchange rate depreciation.

The ERPT for the risk premium regional shocks have a diverse result compared to their domestic counterparts. Specifically for Brazil and Peru the ERPT of the regional risk premium is almost the same degree as for their domestic risk premium shock. On the other hand, Chile and Mexico have a lower degree of the ERPT for the regional case. It is intricate to understanding the reason behind the differences in the results across the countries between the regional and domestic shocks. The relative relevance of the trade partnership with the big economies may helps to explain this conundrum. For Mexico, for example, only 2.4% of their trade balance is with the other Latin America countries which damping any shock that comes from this region. However, this feature does not explain the Chile's result since it weighted percentage trade balance is similar with the Brazil's one. Certainly there are others characteristics not included in the model that may help to explain this results. Finally, regarding the size of the ERPT coming from the monetary policy regional shock is comparable with the domestic monetary policy shock. As the output gap remains quite stable after this shock, the foreign channel is less relevant in this case and may justify the equivalent result between the domestic and regional shocks.

As mentioned before, we consider two global shocks. The first one analyzed is an uncertainty shock that hits the big economies. In this case we see a diverse ERPT across the countries with some having a negative ERPT and others ones with the usual positive ERPT. The point here is that the output is highly impacted for this event and even with a depreciation of the exchange rate, the inflation rate is not affected too much by this cost pressure. In general, only Brazil has a sizeable positive ERPT but at longer horizons. The commodity/demand shock presents an interesting case, with all countries experiencing a negative ERPT. The exchange rate appreciates contemporaneously following the shock and the inflation rate rises a little at the same time. This price level behavior may be due to the strong domestic GDP growth with the exchange rate appreciation working to avoid additional increases in the CPI. This feature should be highlighted since we have at least two factors contributing to increase the GDP: a rise in the foreign demand and a commodities prices increment. Interesting, during the years 2002-2008 the region has experienced a period with these characteristics and the exchange rate appreciation due to the the commodities prices increase, might have supported a lower inflation rate through these years.

Table 4.1 - Accumulated exchange rate pass-through - Latin Countries

Brazil

	Local shocks				Regional shocks		Global shocks	
	Exchange Rate	Risk Premium	Monetary Policy	Demand	Risk Premium	Monetary Policy	Commodities/Demand	Uncertainty
t	0.03	0.06	0.06	0.17	0.05	0.05	-0.01	-0.01
t+1	0.07	0.13	0.13	0.30	0.11	0.12	0.02	0.18
t+2	0.09	0.17	0.16	0.36	0.13	0.16	0.03	0.27
t+3	0.10	0.18	0.18	0.39	0.15	0.18	0.04	0.29
t+4	0.10	0.19	0.19	0.41	0.15	0.18	0.04	0.29

Chile

	Local shocks				Regional shocks		Global shocks	
	Exchange Rate	Risk Premium	Monetary Policy	Demand	Risk Premium	Monetary Policy	Commodities/Demand	Uncertainty
t	0.11	0.19	0.16	0.38	0.08	0.11	0.03	-0.03
t+1	0.14	0.25	0.20	0.48	0.10	0.16	-0.02	-0.12
t+2	0.15	0.26	0.21	0.51	0.12	0.17	-0.06	-0.17
t+3	0.15	0.27	0.21	0.52	0.12	0.18	-0.11	-0.21
t+4	0.16	0.27	0.21	0.52	0.13	0.19	-0.14	-0.25

Colombia

	Local shocks				Regional shocks		Global shocks	
	Exchange Rate	Risk Premium	Monetary Policy	Demand	Risk Premium	Monetary Policy	Commodities/Demand	Uncertainty
t	0.03	0.06	0.07	0.34	0.06	0.06	-0.01	0.00
t+1	0.06	0.11	0.09	0.50	0.11	0.09	-0.05	0.05
t+2	0.07	0.13	0.10	0.58	0.14	0.10	-0.08	0.03
t+3	0.07	0.13	0.10	0.64	0.15	0.10	-0.10	0.02
t+4	0.07	0.14	0.10	0.68	0.15	0.10	-0.12	0.01

Mexico

	Local shocks				Regional shocks		Global shocks	
	Exchange Rate	Risk Premium	Monetary Policy	Demand	Risk Premium	Monetary Policy	Commodities/Demand	Uncertainty
t	0.03	0.14	0.11	0.29	0.10	0.12	0.03	0.01
t+1	0.03	0.15	0.11	0.31	0.11	0.13	0.04	0.01
t+2	0.03	0.15	0.11	0.32	0.12	0.13	0.05	0.01
t+3	0.03	0.15	0.11	0.32	0.12	0.13	0.04	0.01
t+4	0.03	0.15	0.11	0.32	0.12	0.13	0.04	0.01

Peru

	Local shocks				Regional shocks		Global shocks	
	Exchange Rate	Risk Premium	Monetary Policy	Demand	Risk Premium	Monetary Policy	Commodities/Demand	Uncertainty
t	0.13	0.18	0.20	0.51	0.13	0.15	0.05	0.12
t+1	0.18	0.24	0.25	0.67	0.21	0.24	-0.10	0.13
t+2	0.19	0.25	0.26	0.72	0.23	0.27	-0.19	0.02
t+3	0.19	0.25	0.26	0.74	0.24	0.28	-0.28	-0.03
t+4	0.19	0.25	0.26	0.75	0.24	0.29	-0.35	-0.07

The exchange rate pass-through is calculated by $\frac{dp_{0,t+i}}{ner_0}$ where dp is the change of prices from a period t to i and ner is the change of the nominal exchange rate on impact

5 Robustness analysis

As a robustness exercise we have estimated the model with two and 3 lags with no changes in the sign restriction identification. The results remains similar. Another exercise is to consider only 1 period horizon for the sign restriction. Although the sign restriction are applied for more periods in the literature, we relax this assumption and consider a shorter horizon. There is no deep change in the results with those alternative specifications and they are available upon request.

6 Conclusion

Analyse the exchange rate pass-through considering its source is something that the literature only recently has began to research. A more common way to investigate the ERPT is control for some variables that might affect the phenomenon. According to this strategy, it is possible to find some stylized facts for the ERPT as for example the role of the economic activity, the reaction of the central bank, the level and volatility of the CPI and so on. However, investigating the source of the exchange rate movement has its importance since the economic variables that will affect the magnitude of the exchange rate might react differently conditionally on these shocks. This paper has shown that it is crucial to identify the shocks sources to figure out the magnitude of the ERPT.

We have seen that the inflation rate response varies according to the shock applied. If we take a simple exchange rate shock, the price level reacts weaker than the other identified shocks. This feature reveals the importance of identify the shock as they play an important role to determine the magnitude of the exchange rate pass-through. Actually, the output gap is one of the main factors to determine the size of the ERPT. As attested when the economy is in an expansion cycle, the ERPT is higher making the GDP reaction crucial to our results. This can be seen for the domestic demand shock which is the higher ERPT, where the GDP is growing fast at the time when the exchange rate depreciates. An additional important economic characteristic is the level (and so the volatility) of the CPI when the exchange rate appreciates/depreciates. As higher is the price level at the moment of the shock, higher is the exchange rate pass-through. In the demand shock, both features applies what might explain this higher exchange rate pass-through.

The exchange rate pass-through coming from the domestic risk premium shock and the domestic monetary policy shock have similar magnitudes between them for each country. For some countries like Chile and Mexico, the risk premium shock is slightly higher in terms of the exchange rate pass-through, than the monetary policy shock. The output gap response to these shocks might explain these different results, especially for Chile.

We also have considered regional Latin America shocks. We have analysed two shocks, a regional risk premium shock, where is a risk premium shock that hits all the countries at the same time, and a regional interest rate shock. The magnitude of ERPT coming from these regional shocks are not so different than their domestic counterpart. Regarding the regional risk premium shock, for Brazil and Peru the ERPT is almost identical, but for Colombia the regional shock is stronger. On the other hand, Chile's and Mexico's price level are less impacted for this regional shock. For the regional monetary policy shock, the ERPT is similar with the domestic counterpart shock for all countries.

Finally, a global demand/commodities shock and an uncertainty shock are investigated. The ERPT from the uncertainty has the opposite sign which means that we have a decrease in the price level following a depreciation of the exchange rate. This weird result might be due to the other variables responses, since the economy enters in a recession cycle contemporaneously after this shock. In relation to the demand/commodities shocks, it is very interesting because it looks like that we have a positive supply shock at shorter horizons instead of a demand shock in the Latin America countries since the GDP rises and the inflation decreases. This result shows how important are the commodities prices for those economies.

References

An, L, Wang, J. (2011). Exchange Rate Pass-through: Evidence Based on Vector Autoregression with Sign Restrictions. *Federal Reserve Bank of Dallas - Globalization Institute Working Paper 70*.

An, L, Wynne, M A., Zhang, R (2020). Shock-Dependent Exchange Rate Pass-Through: Evidence Based on a Narrative Sign Approach. *Federal Reserve Bank of Dallas - Globalization Institute Working Paper 379*.

Arias, E. J., Caldara, D., Rubio-Ramírez, J. F. (2019). The systematic component of monetary policy in SVARs: An agnostic identification procedure. *Journal of Monetary Economics* 101, pp. 01–13.

Baumeister, C., Hamilton, J. D. (2019). Structural Interpretation of Vector Autoregressions with Incomplete Identification: Revisiting the Role of Oil Supply and Demand Shocks. *American Economic Review* 109, pp. 1873–1910.

Böck, Maximilian, Feldkircher, Martin, Huber, Florian (2020). *BGVAR: Bayesian Global Vector Autoregressions with Shrinkage Priors in R*. Working paper 395. Federal Reserve Dallas.

Campa, J. M., Goldberg, L. (2005). Exchange rate pass-through into import prices. *The Review of Economics and Statistics* 87, pp. 660–679.

Choudri, U. E., Hakura, D. S. (2006). Exchange Rate Pass-Through to Domestic Prices. Does the inflationary environment matter? *Journal of International Money and Finance* 25, pp. 614–639.

Comunale, M., Kunovac, Davor. (2017). Exchange rate pass-through in the euro area. *ECB Working Paper 2003*.

Corbo, V.and P. Di Casola (2018). Conditional Exchange Rate Pass-Through: Evidence from Sweden. *Riksbank Research Paper Series No. 175*.

Correa, A. S., Minella, A. (2010). Nonlinear mechanisms of the exchange rate pass-through: A Phillips curve model with threshold for Brazil. *Revista Brasileira de Economia* 64(3), pp. 231–243.

De Mendonça, H. F., Tiberto, B. P. (2017). Effect of credibility and exchange rate pass-through on inflation: An assessment for developing countries. *International Review of Economics and Finance* 50, pp. 196–244.

Donayre, L., Panovska, I. (2016). State-dependent exchange rate pass-through behavior. *Journal of International Money and Finance* 64, pp. 170–195.

Feldkircher, M, Gruber, T., Huber, F. (2019). International effects of a compression of euro area yield curves. *Journal of Banking and Finance*.

Feldkircher, M., Huber, F. (2015). The International Transmission of US Shocks – Evidence from Bayesian Global Vector Autoregressions. *European Economic Review*.

Forbes, K., Hjortsoe, I., Nenova, T. (2018). The shocks matter: Improving our estimates of exchange rate pass-through. *Journal of International Economics* 114(1), pp. 255–275.

Forbes, K., Hjortsoe, I., Nenova, T. (2020). International evidence on shock-dependent exchange rate pass-through. *NBRE - Working Paper 27746* August 2020, pp. 255–275.

Ha, J. D., Stocker, M. M., Yilmazkuday, H. (2020). Inflation and exchange rate pass-through. *Journal of International Money and Finance* 105.

Kearns, J, Patel, N. (2016). Does the financial channel of exchange rates offset the trade channel. *BIS Quarterly Review, - December 2016*.

Mishkin, F. S. (2007). Inflation Dynamics. *International Finance* 10(3), pp. 317–334.

Mishkin, F. S. (2008). Exchange rate pass-through and monetary policy. *NBER Working Paper Series* 13889.

Mohaddes, K., Raissi, M. (2020). Compilation, Revision and Updating of the Global VAR (GVAR) Database, 1979q2-2019q4. *University of Cambridge: Faculty of Economics (Mimeo)*.

Pesaran, M. H., Schuermann, T., Weiner, S. M. (2004). Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model. *Journal of Business & Economic Statistics*, pp. 129–162.

Przystupa, J., Wróbel, E. (2011). Asymmetry of the exchange rate pass-through. *Eastern European Economics* 49(1), pp. 30–51.

Shambaugh, J. (2008). A new look at pass-through. *Journal of International Money and Finance* 27, pp. 560–591.

Sims, A. C. (1980). Macroeconomics and Reality. *Econometrica* 48, pp. 01–48.

Taylor, J. B. (2000). Low Inflation, pass-through, and the pricing power of firms. *European Economic Review* 44(7), pp. 1389–1408.

Uhlig, H. (2005). What are the effects of monetary policy on output?Results from an agnostic identification procedure. *Journal of Monetary Economics* 52, pp. 381–419.

Uhlig, H. (2017). Shocks, Sign Restrictions, and Identification, pp. 95–127.

Appendix A

Table A.1 - Trade Weighted Matrix - Latin Countries

	AR	BR	CH	CO	CN	EU	JA	ME	PE	US
AR	0.0%	37.2%	5.4%	24.5%	1.4%	6.2%	2.3%	3.6%	2.2%	17.2%
BR	9.0%	0.0%	3.3%	33.6%	1.6%	21.4%	3.5%	3.5%	1.4%	22.6%
CH	3.8%	8.6%	0.0%	35.8%	1.8%	14.6%	8.3%	3.2%	2.6%	21.3%
CN	0.8%	6.4%	2.4%	0.0%	0.8%	29.3%	19.3%	3.4%	1.4%	36.0%
CO	1.6%	6.6%	2.7%	21.2%	0.0%	16.2%	2.7%	8.2%	2.9%	37.9%
EU	1.1%	4.2%	1.2%	36.6%	0.8%	0.0%	9.1%	4.4%	0.7%	41.9%
JA	0.2%	1.6%	1.3%	44.2%	0.3%	18.0%	0.0%	2.5%	0.4%	31.6%
ME	0.3%	1.4%	0.5%	11.7%	0.7%	8.0%	3.0%	0.0%	0.3%	74.2%
PE	2.4%	6.4%	3.9%	35.7%	3.5%	14.9%	4.8%	3.6%	0.0%	24.7%
US	0.6%	3.2%	1.2%	28.8%	1.3%	27.5%	9.7%	26.9%	0.8%	0.0%

Note: The lines represent the wheighted trade flows between the countries and must sum up 1. For Europe Union, I consider the sum of the following countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. The data source is from the United Nations data: https://comtrade.un.org/data

Table A.2 - F test:first order serial autocorrelation of cross-unit residuals

>0.1	30	54.55%
0.05-0.1	2	3.64%
0.01-0.05	3	5.45%
<0.01	20	36.36%

Table A.3 - Average pairwise cross-unit correlation of unit-model residuals

p-values	*y*		*dp*		*ner*		*EMBI*		*IR*		*poil*		*pmat*		*pmetal*		*VIX*	
<0.1	7	70.0%	10	100.0%	1	10.0%	5	83.33%	3	30.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
0.1-0.2	3	30.0%	0	0.0%	3	30.0%	0	0.0%	6	60.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
0.2-0.5	0	0.0%	0	0.0%	6	60.0%	1	16.67%	1	10.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
>0.5	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3	100.0%	2	100.0%	2	100.0%	2	100.0%

Shock Dependent Exchange Rate Pass-Through - An Analysis for Latin American Countries

José Luiz Rossi Júnior
João Paulo Madureira Horta da Costa

September 2023

Inter-American Development Bank