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

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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 enables us to allow spillover between countries mimicking the real conditions when the shocks hit the economies. Four domestic shocks for each Latin American country 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. Additionally, two regional shocks are considered: a regional monetary policy shock, an event in which the region raises its interest rate, and a regional risk premium shock, where the risk premium rises simultaneously. For most countries, the exchange rate pass-through coming from those regional shocks is 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 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 time.

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

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1   Introduction

Exchange rate pass-through is a topic that always comes into the discussion when the exchange rate volatility arises. Emerging countries face this volatile environment more periodically, and understanding its consequences is imperative for policymakers. The exchange rate pass-through (ERPT henceforth) is defined as the degree of the exchange rate movements transmitted to the domestic price level. This ERPT definition explains much of the importance of understanding how it evolves through the economy and 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 also has 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 evidence that the average inflation determines the degree of the pass-through dominating other 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 exchange rate depreciation.

The volatility of the inflation rate is consensual as one of the main factors that influences the degree of ERPT. However, it seems that the 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) argues that price shocks are mitigated when the inflation expectations are anchored, particularly shocks 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 shows us that when the 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 an expansion cycle has 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 price increases. 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 begun to investigate the ERPT: the source of the exchange rate movements. The idea here is to extract information about the kind of shocks that are hitting the exchange rate since the other variable's 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 determining the degree of the ERPT, their usual response provides information about what we can expect from the ERPT. This shock-dependent ERPT study was pioneered first by Shambaugh (2008) but without a closer look at its determinants.

Based on a general open economy framework, Forbes et al. (2018) provides intuition about how the exchange rate movements translate to the domestic prices, taking into 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 the persistence of the exchange rate movement can better explain the magnitude of the ERPT. Using a VAR with sign restrictions for the United Kingdom, they found 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 exchange rate appreciation, 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 recent years. Studies for specific countries or groups 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 studies 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 analyze 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 highest degree of pass-through respectively. However, those chapters that consider more than one country do not link the countries with each other, and analyze the shock-dependent ERPT individually.

This chapter contributes to the literature by applying a methodology to differentiate the shock by its origins divided into domestic, regional, and global events to analyze the ERPT. We apply the Global VAR (GVAR) approach that is built up to analyze the shocks spillover between countries, considering the relationship between them. In this sense, the Global VAR (GVAR) representation allows us to use the VAR either for a single country or for a group of countries and makes it possible to identify the shock by country and region. 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 to a set of 5 Latin American countries - Brazil, Chile,

Colombia, Mexico, and Peru. These groups of countries make a good case study since all countries, besides their geographical location, share several macroeconomic similarities with floating exchange rate regimes within an inflation-targeting regime, and are significant trade partners.

The chapter is organized as follows: the econometric methodology and the data sample are shown in the next section. The third section presents the identification strategy followed in the fourth section by the estimation results 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 in 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 shock 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 such, Pesaran et al. (2004) proposed a way to estimate VARs, including spillover effect and at the 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 is estimated with its 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:

$$x_{it} = a_{i0} + a_{i1t}t + \phi_i x_{it-1} + \Lambda_{i0}x_{it}^* + +\Lambda_{i1}x_{it-1}^* + \varepsilon_{it} \tag{1}$$

where: a_{i0} and $a_{i1t}t$ 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 lagged endogenous coefficient.

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[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.

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 $\Lambda_{i0} = \Lambda_{i1} = 0$, 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 are 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 represent the bilateral connection between the countries. It is worth noting that this bilateral linkage ω_{ij} is 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 con-

temporaneous 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:

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

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 such, it makes it 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 parameter estimates. A usual VAR contains $n + pn^2$ coefficients where n is the number of parameters and p is 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 an 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 a smaller 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) which 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 these smart properties of the SSVS prior but recommend those papers if any doubt remains open.

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:

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

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

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Where δ_{ij} is a random binary variable, assuming 1 if 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 components, with $\tau^2_{ij,0} >> \tau^2_{ij,1}$ and $\tau^2_{ij,1}$ set close to 0. Those prior variances mean that if there is a small coefficient in the model, the spikes component applies, pushing the posterior distributions toward zero. On the other hand, if the coefficient is higher, little shrink is used, leaving 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 $\delta_{ij} = 1$, 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 on 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. On 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 the variance-covariance, I also follow an SSVS prior specification. But before introducing this, it is important to mention that I assume stochastic volatility for the variance-covariance in the estimation process. The stochastic volatility sets 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 has some parameters that can make the stochastic volatility given in Equation (10) work like

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

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

a homoscedastic case or a more volatile one. To see this, let SSVS prior to the variance-covariance be represented by:

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

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 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 homoscedasticity 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 normal 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 distribution 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 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 considered a lag 1 BGSVAR with 60000 draws and 30000 burn-ins. Its descriptive statistics are 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 were first shown by Uhlig (2005). This kind of restriction was developed to avoid strong contemporaneous restrictions that usually come with the Cholesky decomposition. The sign restrictions employ an agnostic identification scheme based on a solid assumption of what is going on with the data or how this data usually responds to a shock. Uhlig (2017) justifies his method by giving interesting examples of how we can apply sign restrictions based on these good premises. Regarding Uhlig (2017) lessons, it is possible, in the context of the exchange rate pass-through, to insert a sign restriction taking into consideration some assumptions. For example, it is expected that after an exchange rate depreciation, consumer prices do

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[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.

not decrease, and the risk premium increases at the same time. Hence, we might apply this sign restriction if it is supported by theory or empirical evidence.

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 does not erase the GVAR appeal because it would be very difficult to defend an identification scheme for foreign variables. The GVAR has another interesting feature 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:

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

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, $\tilde{a}_{i0,t} = R_{0,t}a_{i0,t}$, $\tilde{a}t_{i0,t} = R_{0,t}at_{i0,t}$, $\tilde{\phi}_{i1,t} = R_{0,t}\phi_{i1,t}$, $\tilde{\Lambda}_{i0,t} = R_{0,t}\Lambda_{i0,t}$ 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 at each point in time. Notice that equation 12 is equation 1 with the matrix R applied to it and considering that it 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 restrictions decreases the uncertainty of the model, but it makes it harder to find a rotation matrix. So it is possible not to find any rotation matrix if the model is very restricted.

2.1 Data sample

We followed two directives for the data sample chosen: the first and most important is the need for 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 analyzed should have at least the GDP, the inflation rate, the nominal exchange rate, and the interest rate on a quarterly basis in a wider span.

In line with these directives, we cover five Latin American 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:

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

where: y 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 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 their prices by their demand movements. At the same time, we add the VIX for Europe and the USA as a source of volatility shock. The country-specific VAR estimation variables can be seen above:

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

The commodity index is separated by its class. The *fuel*, *agri*, and *met* denote the log differences of the Fuel, Agriculture, and Metal prices indexes respectively[9]. we have separated the

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[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 shock 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 are from Mohaddes and Raissi (2020) but it has been transformed into an annualized basis series. For Colombia, the data comes from the official National Bureau statistics and Colombia's Central Bank.

[9]The commodities indexes are from the Primary Commodity Price System of the IMF. The Agriculture index comprehends the 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.

commodities by their 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 the richest analysis 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 in determining the price of these products.

The dynamics of the Latin countries can be modeled by a VARX(p,q) with *k* endogenous variables defined in (13) and *j* weak exogenous variables coming from (14) and the economies of the other 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 other 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 on other countries unless they have a relevant commerce between them 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 are 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 identification strategies have been proposed. Most of these identification schemes have been scrutinized since some of them rely on strong assumptions. These assumptions stem from the fact that we should be confident if these restrictions come from exactly the shock that we are aiming to identify and not due to a linear combination of other shocks.

Taking this under consideration, Uhlig (2005) proposed a new identification strategy, with

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[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.

a minimalist approach, identifying structural shocks through sign restrictions. The idea is to impose a minimal restriction set to avoid controversial identifications. For example, many 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 others support the notion that there is a small contemporaneous effect (Uhlig (2017), Forbes et al. (2018)). Our strategy is to not enter into 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 that 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 contemporaneous GDP reaction after a monetary policy shock, we will leave 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 analyze three sources of shocks for the Latin American countries: (i) a domestic shock of each individual Latin American country, (ii) a regional shock, a shock that hits all the Latin American countries at the 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 has been exhaustively analyzed before, and we will just follow what has been applied. Additionally, we consider an EMBI shock to represent a risk premium shock. The identification of this shock is straightforward: the exchange rate depreciates after a positive risk premium shock, which raises 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 to meet its external debt obligations, like the fiscal balance, business cycle expectation, risk aversion, and terms of trade. In spite of all this, an unidentified exchange rate shock is also considered as a benchmark. [11]

Regarding the regional shock, we contemplate a risk premium and a monetary policy shock 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 relatively common in the region's history and uses non-polemical identification restrictions. Finally, a global shock is analyzed. we consider 2 types of shocks: an uncertainty shock, where the risk aversion goes

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

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 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 endogenous 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 to last 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 behaves 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 it is unfeasible to separate the CPI response considering only the exchange rate movement. Thus, the ERPT is defined as the ratio

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[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.

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 the change of the nominal exchange rate in time 0. This definition is also considered in some related literature, 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 analyzed 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 manners depending on the country analyzed, with Brazil, Colombia, and Peru experiencing a recession after the exchange rate depreciation and others like Chile having a boom in their economy. This result is in line with An and Wang (2011), which does not find a regular output response for countries after an exchange rate depreciation. These different output reactions 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 in tightening the domestic financial conditions, especially if the country has a large stock of foreign currency borrowing. The prevalence of one of these two channels may explain the different output responses. Note that the higher the inflation rate, the more intense the reaction of the monetary policy, raising the interest rate and contributing to the slowdown of 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 a manner, it is complicated to analyze the exchange rate shock as an event that appears in an 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.

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[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.

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 and Colombia having a higher inflation rate in the subsequent quarters after the depreciation. In all countries, the Central Bank raises its interest rate to combat the inflationary upward pressure. This Central Bank's behavior may contribute to a decrease in 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 that probably comes from some domestic or global stressful event. Thus, even if the Central Bank does not raise the interest rate, the GDP may decrease. Chile and Mexico are the countries in 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, the response of the inflation rate is higher for Chile and Peru.

The demand shock is analyzed 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 shock 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 partnerships in the region. According to Figure 4.5, it is interesting to note that in some countries, such as Brazil, for example, the output grows in the first quarter after the shock, and only after 2 quarters does it begin to enter 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 government expenditure, enhancing the output in the short run

and worsening 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 worsening in Brazil's fiscal balance will not erase the risk premium of all of Latin America. The most suitable explanation is a worsening of the fiscal balance as a 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 joint monetary policy shock in Figure 4.6, called regional monetary policy shock. At the same time, all Latin American countries raised their interest rates. As a consequence, the exchange rate appreciates, and the inflation rate goes down in all countries. This result is quite similar to 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, which 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 has the potential to spread through the world. The first scenario analyzed 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 to be 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 American countries' trade partnerships. 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 looks like that in the uncertainty shock, the strong output response is responsible for the CPI path.

The commodities/demand shock is one of the most interesting shocks analyzed in this chapter since it includes some important characteristics for Latin American 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 affects 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, which shows the relevance of the terms of trade to economic activity. The inflation rate of Colombia and Mexico remains quietly stable despite the strong GDP growth in these countries. On the other hand, Chile and Peru experienced 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 in the risk premium with an appreciation of the exchange rate in time 0.

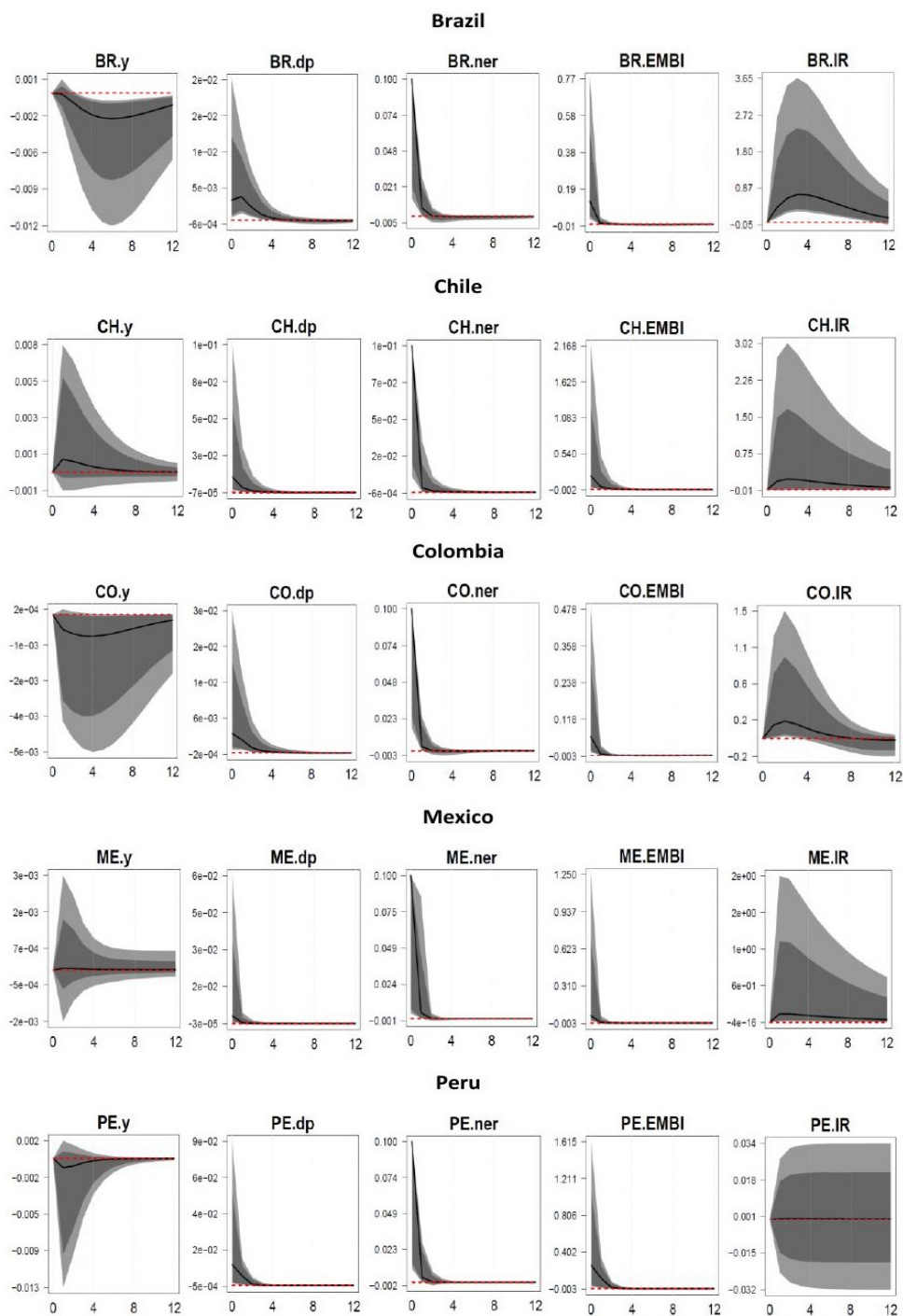# Figure 4.1 - Nominal exchange rate shock - Latin countries

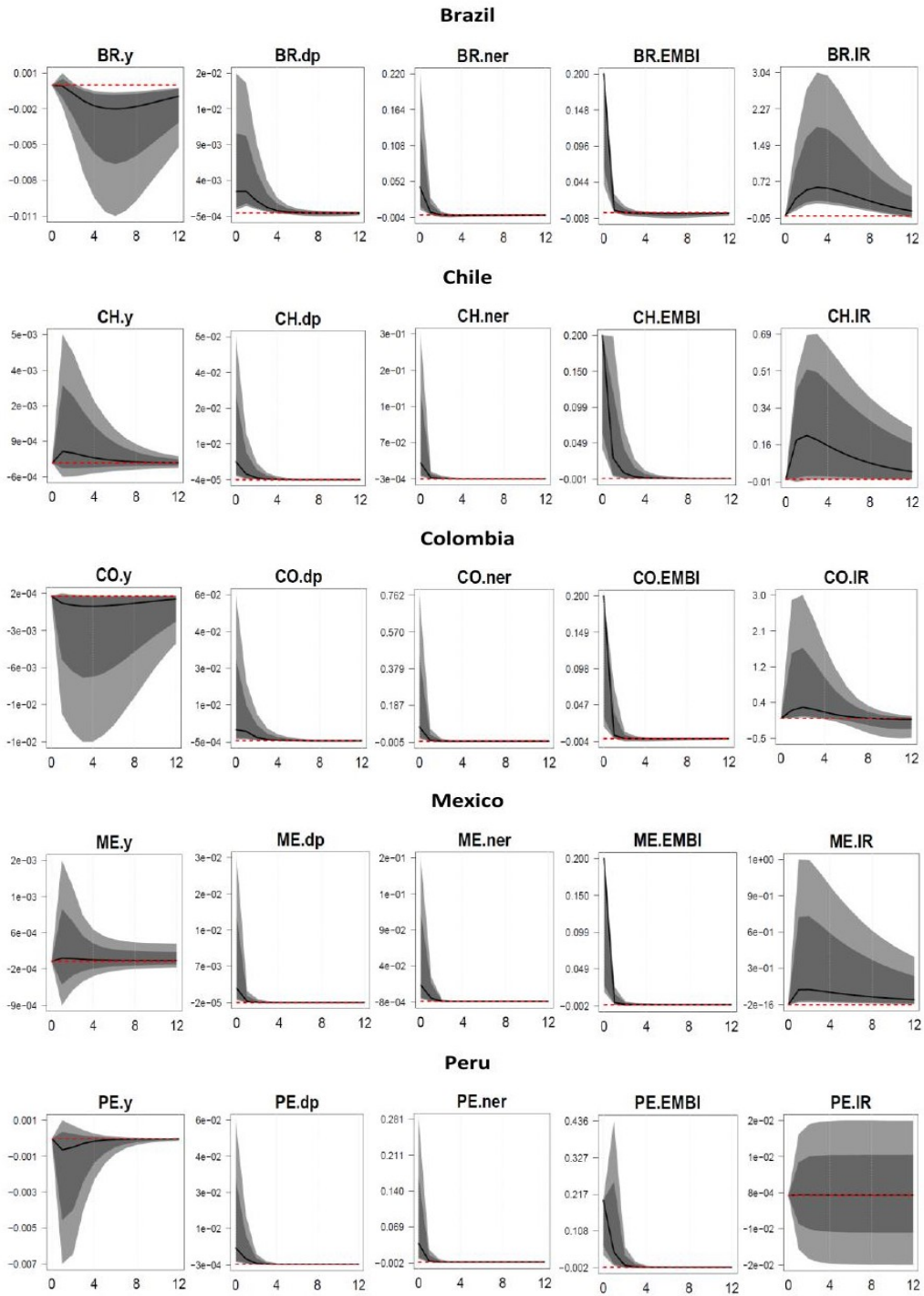## Figure 4.2 - Risk Premium shock - Latin countries

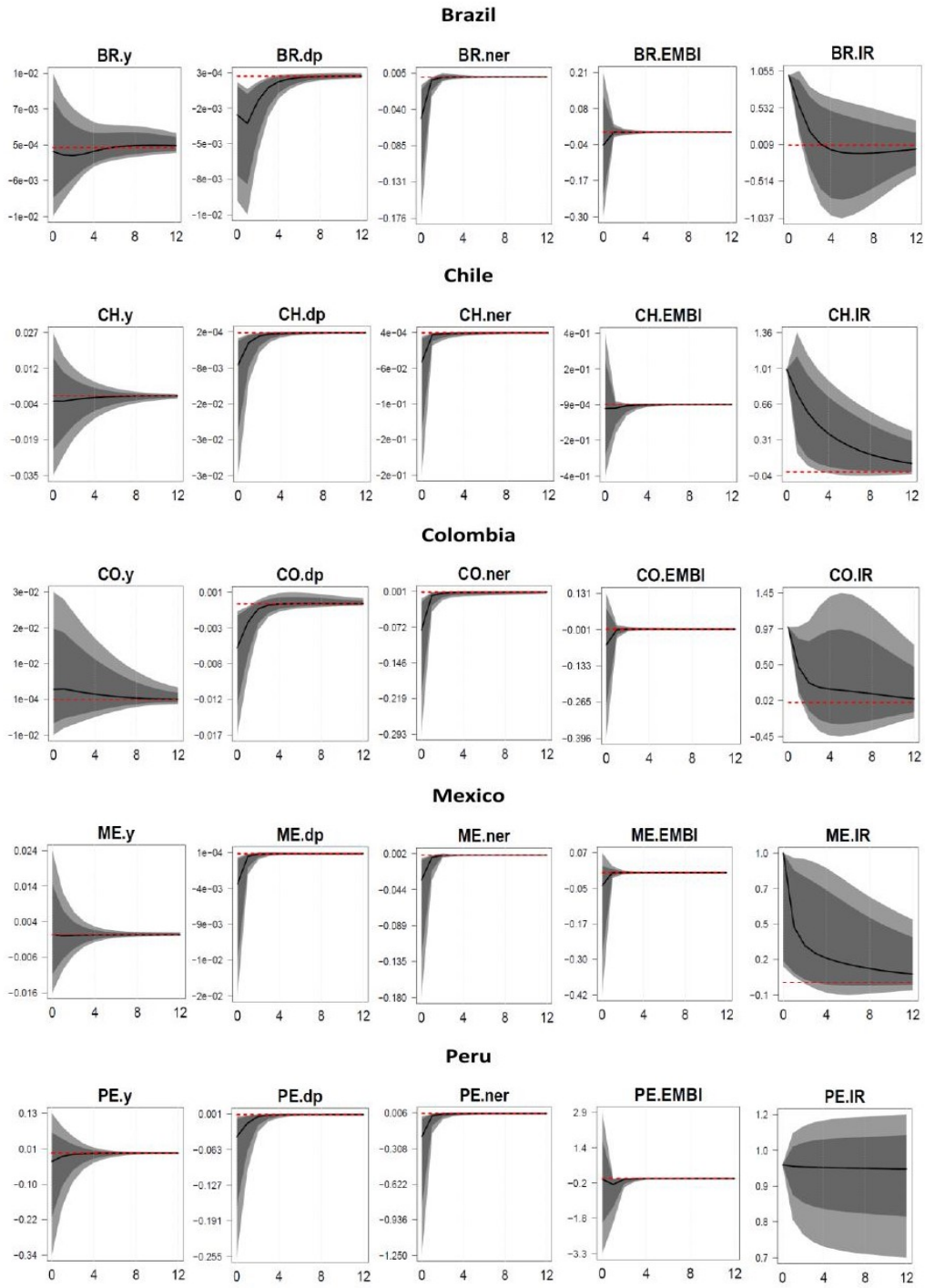# Figure 4.3 - Monetary Policy shock - Latin countries
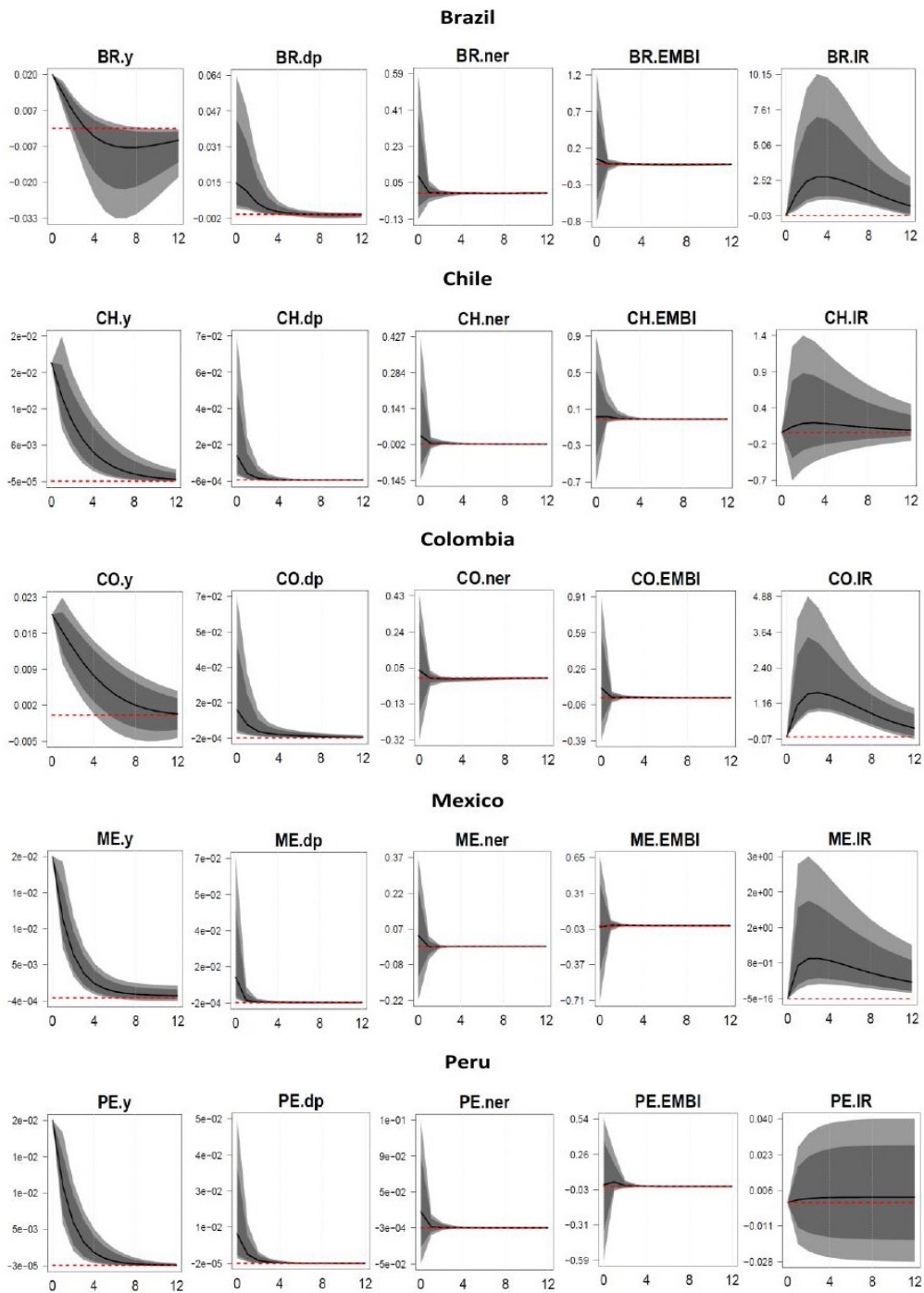
Figure 4.4 - Demand shock - Latin countries

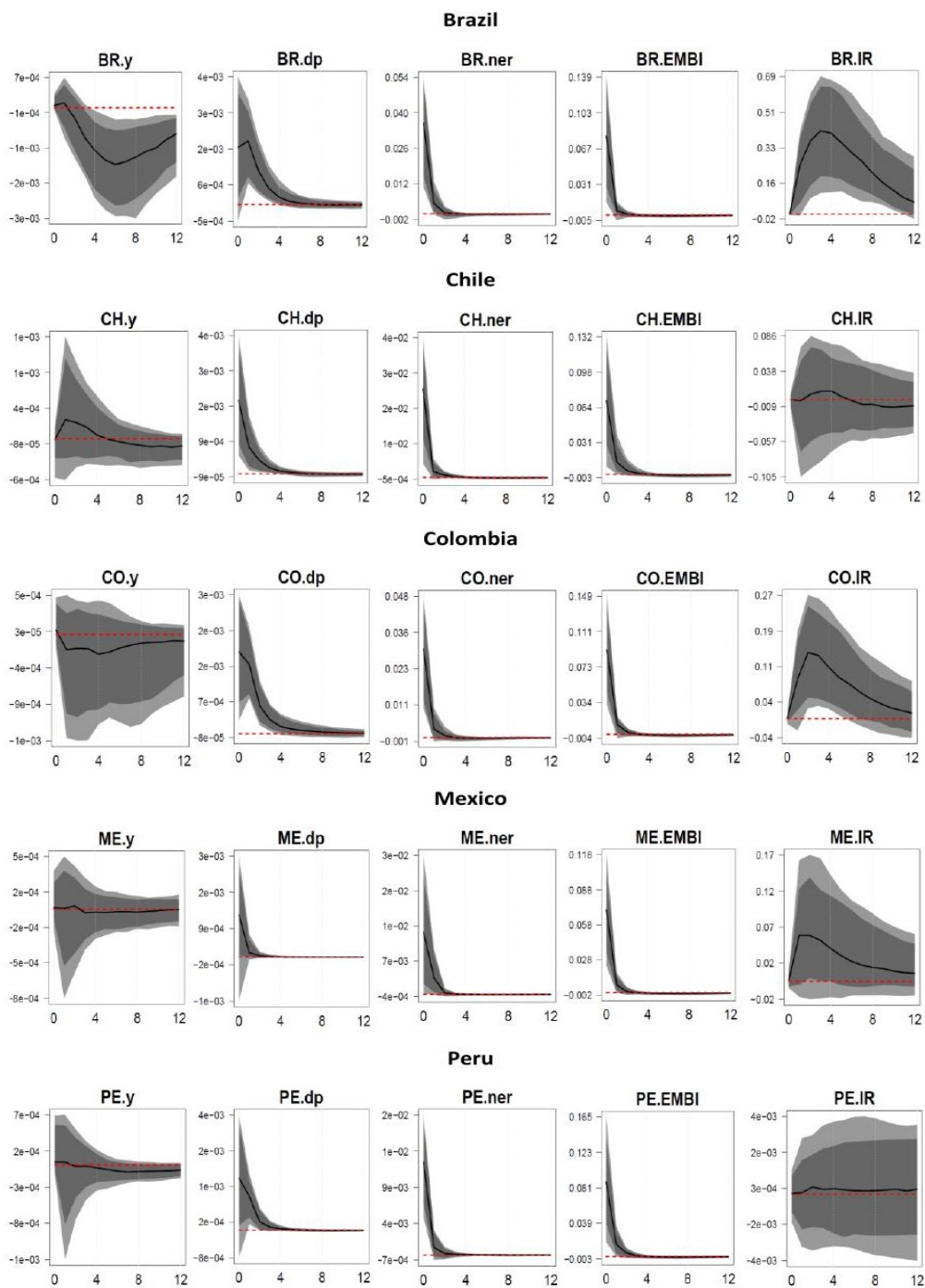Figure 4.5 - Regional Risk Premium shock - Latin Countries

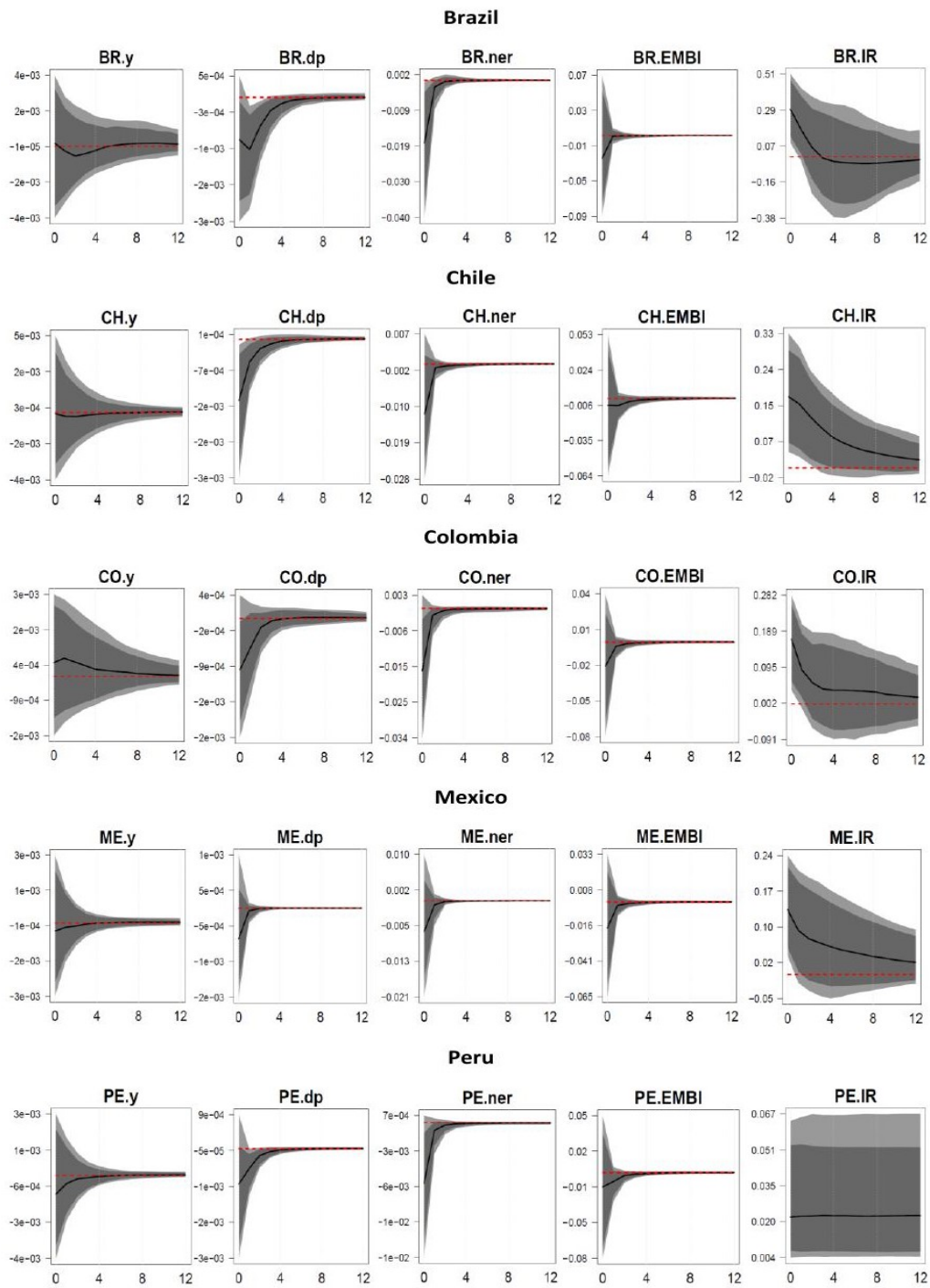# Figure 4.6 - Regional Interest rate shock - Latin Countries

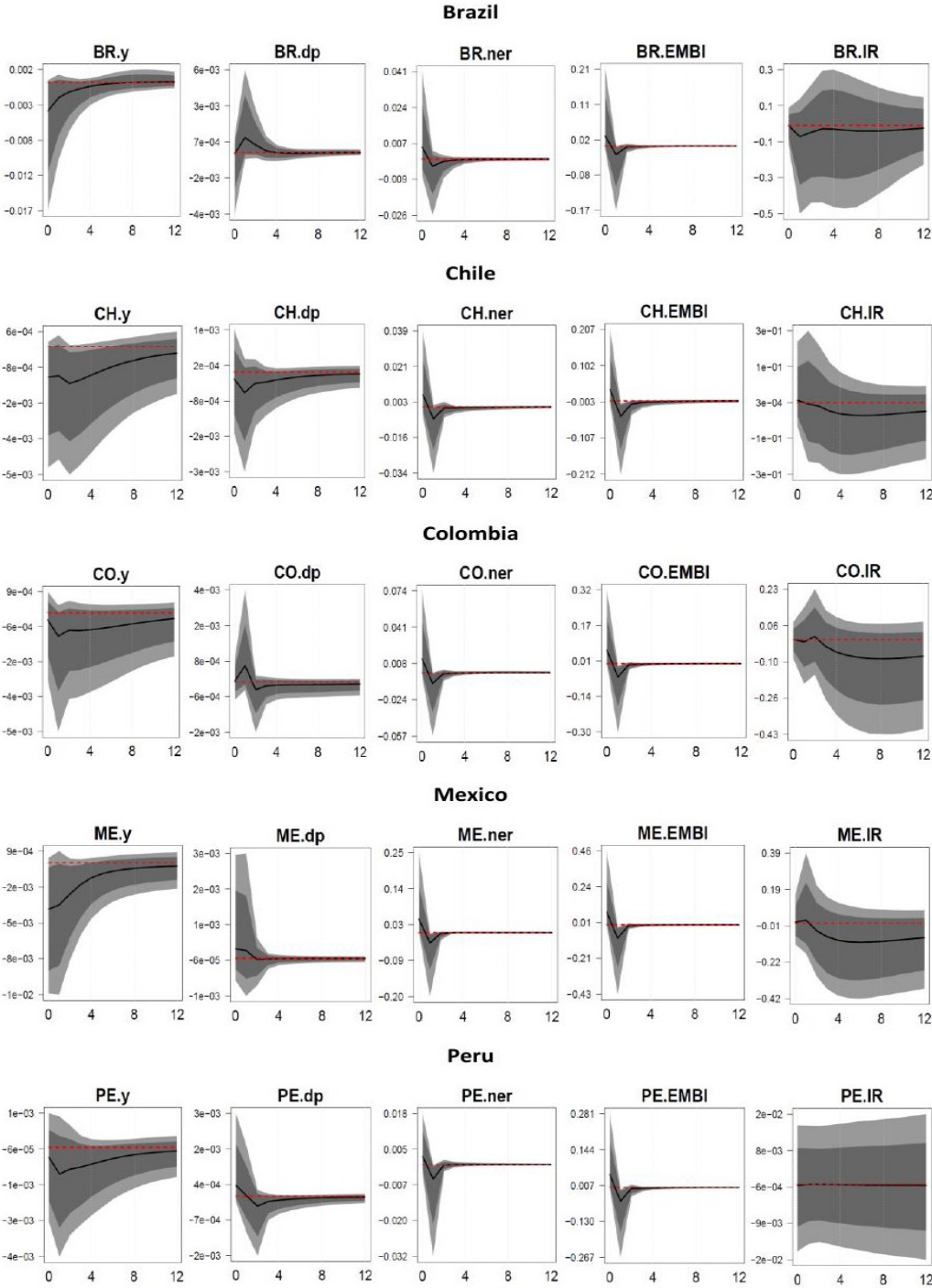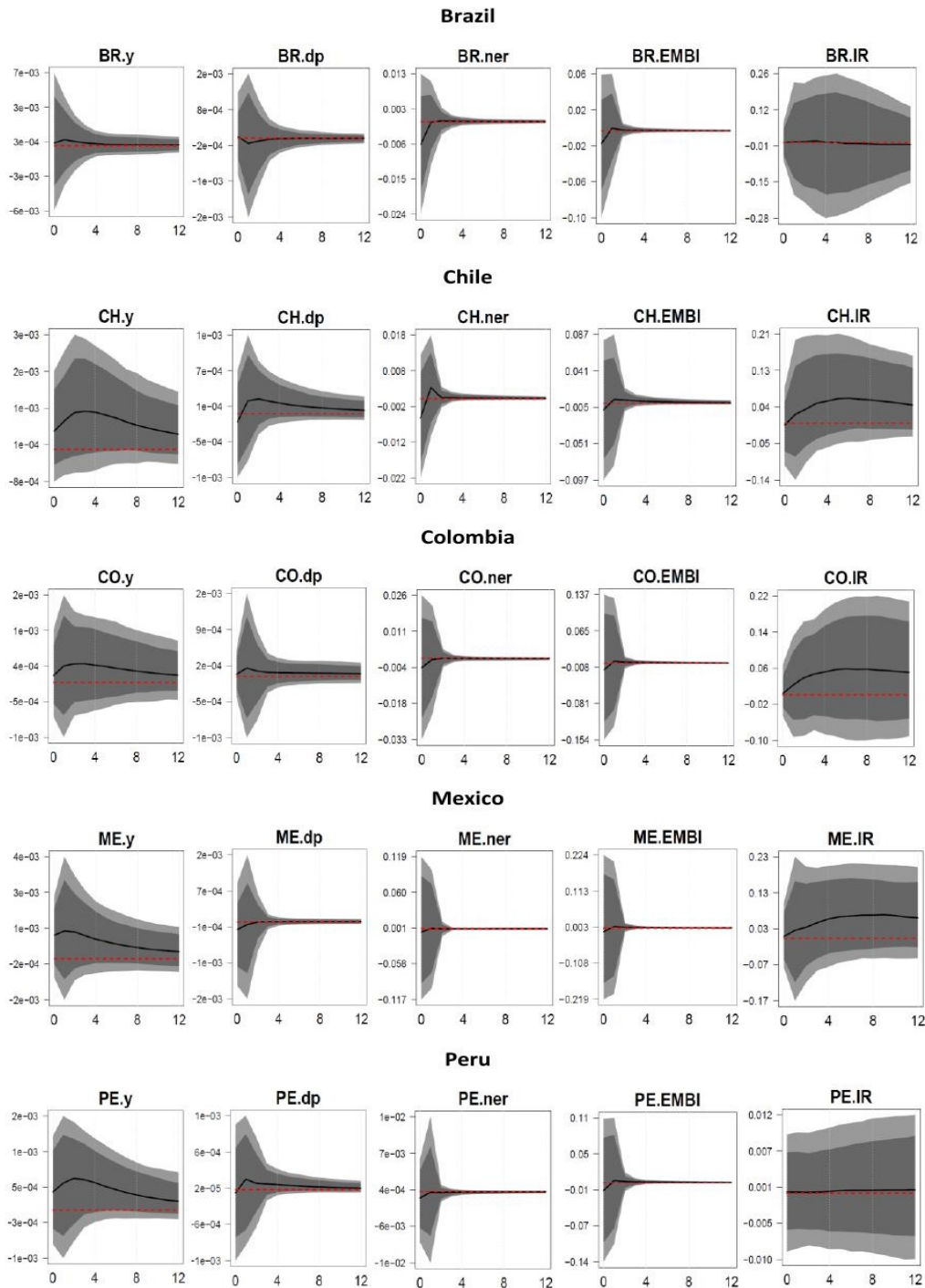# Figure 4.7 - Uncertainty shock - Latin Countries

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 gives us a number of how different the pass-through for each of the shocks analyzed 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 identifying 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 to the risk premium shock.

The domestic demand shock exhibits the highest magnitude of the ERPT. This result might come from the fact that this shock covers some economic features that 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 contrasts 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 found here for a depreciation event: if the price setters have no incentive to decrease prices when they face 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 has 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 important to understand 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 help to explain this conundrum. For Mexico, for example, only 2.4% of their trade balance is with the other Latin American countries, which dampens any shock that comes from this region. However, this feature does not explain Chile's result since its weighted percentage trade balance is similar to Brazil's. Certainly, there are other characteristics not included in the model that may help to explain these 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 with the usual positive ERPT. The point here is that the output is highly impacted by 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. Interestingly, during the years 2002-2008, the region experienced a period with these characteristics, and the exchange rate appreciation due to 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 check, we estimated the model using an alternative identification scheme. Specifically, we allowed the monetary policy to respond contemporaneously to the shocks outlined in Table 3.1 as can be seen in Table A.4 in Appendix A which shows the identification applied in this context. Given that our model is estimated in a quarterly time frame, it's reasonable to allow the central bank to react within the same quarter as the shock. The results remain largely consistent with our primary findings.

For most countries, except Mexico, the domestic demand shock continues to exhibit the most significant ERPT. On the other hand, for certain countries, the ERPT from the risk premium shock is lower than to the ERPT from the exchange rate shock. However, both shocks are still relevant to explain the magnitude of the ERPT and show the central role of how the central bank reacts to those shocks. Finally, our findings related to regional and global shocks show similar magnitudes of ERPT, underscoring the robustness of our results.

Table 4.2 - Accumulated exchange rate pass-through (alternative identification) - 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	0.04	0.06	0.20	0.06	0.05	-0.01	-0.01
t+1	0.07	0.10	0.13	0.33	0.15	0.12	0.02	0.18
t+2	0.09	0.14	0.18	0.38	0.19	0.15	0.03	0.27
t+3	0.10	0.15	0.20	0.39	0.20	0.16	0.04	0.29
t+4	0.10	0.16	0.21	0.39	0.21	0.17	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	0.30	0.19	0.16	0.25	0.28	0.14	0.03	-0.03
t+1	0.39	0.25	0.19	0.33	0.38	0.18	-0.02	-0.12
t+2	0.42	0.26	0.20	0.36	0.42	0.20	-0.06	-0.17
t+3	0.43	0.27	0.20	0.38	0.44	0.21	-0.11	-0.21
t+4	0.44	0.27	0.19	0.38	0.45	0.22	-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	0.10	0.07	0.06	0.82	0.13	0.06	-0.01	0.00
t+1	0.15	0.10	0.09	1.13	0.15	0.09	-0.05	0.05
t+2	0.17	0.11	0.10	1.20	0.17	0.10	-0.08	0.03
t+3	0.18	0.12	0.10	1.22	0.18	0.11	-0.10	0.02
t+4	0.18	0.12	0.10	1.21	0.19	0.11	-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	0.11	0.09	-0.65	0.09	0.09	0.03	0.01
t+1	0.04	0.12	0.10	-0.68	0.09	0.09	0.04	0.01
t+2	0.04	0.13	0.10	-0.69	0.10	0.10	0.05	0.01
t+3	0.04	0.13	0.10	-0.69	0.10	0.10	0.04	0.01
t+4	0.04	0.13	0.10	-0.69	0.10	0.10	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	0.31	0.20	0.08	0.92	0.23	0.18	0.05	0.12
t+1	0.38	0.28	0.16	1.05	0.33	0.27	-0.10	0.13
t+2	0.39	0.30	0.19	1.06	0.37	0.31	-0.19	0.02
t+3	0.39	0.30	0.20	1.06	0.38	0.32	-0.28	-0.03
t+4	0.39	0.30	0.20	1.05	0.39	0.33	-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

6 Conclusion

Analyse the exchange rate pass-through considering its source is something that the literature only recently has begun to research. A more common way to investigate the ERPT is to 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 chapter has shown that it is crucial to identify the shock 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 identifying the shock, as it plays an important role in determining the magnitude of the exchange rate pass-through. Actually, the output gap is one of the main factors in determining 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. The higher the price level at the moment of the shock, the higher the exchange rate pass-through. In the demand shock, both features apply 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, which 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 levels are less impacted by this regional shock. For the regional monetary policy shock, the ERPT is similar to 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 American countries since the GDP rises and the inflation decreases. This result shows how important are the commodities prices for those economies.

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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%

Table A.4 - Identification of alternative specification