FOREIGN SHOCKS AND AGGREGATE PRICE FLUCTUATIONS IN A SMALL COMMODITY EXPORTER ECONOMY

Zulma Barrail

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Zulma Barrail *

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Abstract

This paper examines the role of foreign shocks on aggregate prices in the small net commodity exporter economy of Paraguay. I apply a bayesian methodology for variable choice in VARS and find that foreign variables such as those reflecting regional financial risk and commodity prices are highly relevant in the prediction of aggregate prices in Paraguay. Next, I estimate an over-identified SVAR model with block exogeneity restrictions in order to quantify the effect of shocks in commodity prices and regional risk on key variables, namely the Consumer Price Index, Food CPI, the exchange rate, a monthly indicator of output and the nominal interest rate. Commodity prices shocks explain a substantial percentage of movements in almost all domestic variables, particularly CPI and its food component.

JEL Classification: E31, E32, E52, C32, C52
Keywords: Structural vector autoregression, Bayesian model choice, Commodity prices, inflation, Paraguay's economy

Introduction

Historically, economic fluctuations in developing small open economies have been more volatile than those in their more developed counterparts. This is partially explained by the fact that developing economies have less developed financial systems and that the domestic economy have much less influence on the interest rate on its debt. International

*Research economist. Central Bank of Paraguay.
For comments or suggestions write to zbarrail@bcp.gov.py. I thank my colleagues from Economic Studies, in particular Chief Economist Miguel Mora, Gustavo Biedermann and Cesar Blanco for their support and comments. The views expressed in the paper are mine and do not necessarily reflect those of the Central Bank of Paraguay.

markets are usually more important on the determination of this rate than same country's economic fundamentals. Another distinctive feature of some small open economies is that exports and imports play a larger role in economic activity, making the country more dependent to international markets (Guerron-Quintana, 2013).

Paraguay can be regarded as a special case of a small open economy as it is *highly open*, a striking example of a net agricultural commodity exporter and its trading partners are other important emerging countries. Since the financial system is relatively more closed than those of neighbouring countries, we would expect that greater financial risk in the region is transmitted to the domestic economy mainly through its effect on foreign demand for domestic goods. However, the financial channel of regional or international financial risk may be growing in importance since Paraguay started issuing sovereign bonds in international markets in 2013. These joint characteristics imply that the domestic economy may be highly exposed to fluctuations in prices of key commodity exports, international market of sovereign bonds and foreign demand.

The main purpose of this paper is to study the relevance and the transmission of foreign shocks on aggregate prices, particularly CPI. We first follow the bayesian methodology in Jarocinski and Mackowiak (2016) and take an agnostic approach in variable choice for two Vector Autorregresive Models (VARs) containg CPI. The first VAR attempts to explain CPI main components: food tradables, non food tradables and non tradables. The second VAR contains CPI, domestic output, the nominal interest rate and nominal exchange rate. The applied methodology allow us to rank variables based on how much they help predict variables of interest. These results inform us on the relative relevance of international variables and suggest us on how to extend a simple open economy neokeynesian model for the paraguayan economy.

Next, given previous findings we specify a VAR model which is estimated and identified using valid assumptions for a typical small open economy. To estimate the over identified model with zero restrictions in the lag structure, the Gibbs sampler developed by Waggoner and Zha (2003) is used.

Our research question is relevant as it aims to understand which are the external shocks that matter the most and how they are transmitted to aggregate variables that are monitored regularly by the Central Bank. Studying whether fluctuations in international markets are transmitted to aggregate prices like Consumer Price Index (CPI) is an interesting and novel analysis. This is also the first empirical paper that examines the role of regional risk on aggregate data for Paraguay.

The first section describes the paraguayan economy and two recent events that illustrate the relationship between external conditions and domestic aggregate prices. The second section describes the methodology applied for variable selection and results from the application. The third section takes the previous section findings and describes

the model, the identification strategy and estimation methodology. The foruth section presents estimation results. Lastly, we conclude.

1 Motivation

1.1 A brief description of the paraguayan economy

Paraguay is a special case of a small open economy for various reasons.

First, the country has been described as a *highly open* economy (International Monetary Fund, 2016). A traditional measure of openness (how much a country trades with the rest of the world) is the ratio of exports plus imports to GDP. According to World Bank Data for the period 2006-2016, paraguayan exports and imports represented around 96% of total GDP on average. In comparison, trade openness in Chile is 68% while in Argentina, Brazil, Colombia, Peru and Uruguay this measure ranges from 25% to 55%.

Second, Paraguay is a striking example of a net agricultural commodity exporter. Using data from the United Nations Food and Agricultural Organization (FAO), Blanco (2017) computes net agricultural exports[1] as a percentage of gross domestic product (GDP) for all countries available in the database and for the year 2012. He finds only twelve countries with net agricultural exports (NAE) of at least 5% of GDP. Paraguay and Cote d'Ivoire stand out as the countries with the highest NAE in 2012 (around 13%). In addition, among these twelve countries, Paraguay had the highest increase in NAE over 42 years, i.e NAE in 2012 doubled that of 1970.

Third, Paraguayan exports are concentrated not only on a small number of agriculture products but also a small number of trading partners. During the recent decade 2007-2017, the annual contribution of *agricultural goods*[2] in total exports rose significantly and currently represents around 50% of exports (see Figure 1). In addition, Paraguay sells approximately 60% of its total exports to four countries: Brazil (35.2%), Argentina(11%), Chile (6.3%) and Russia (7.1%) [3].

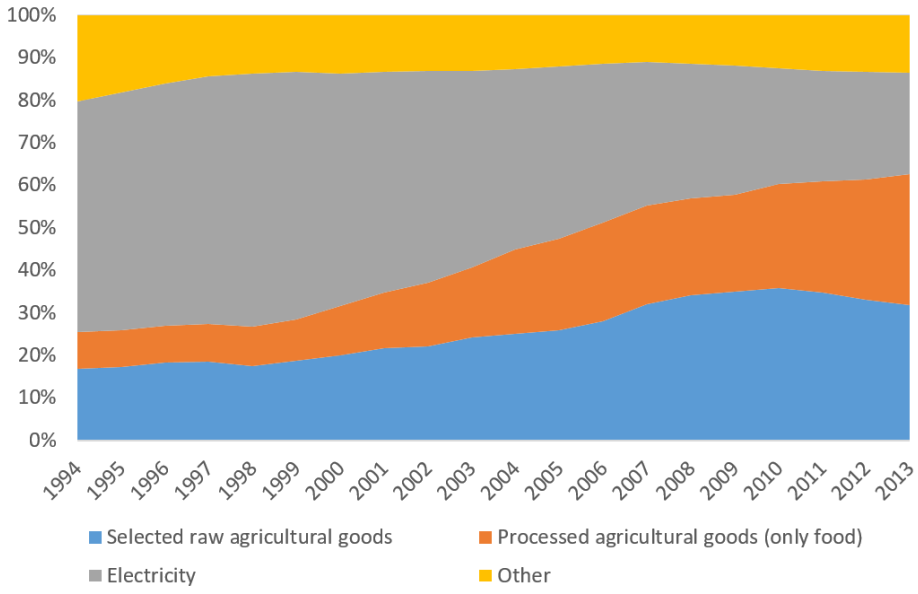
Fourth, the rest of the world from the paraguayan perspective doesn't directly comprise developed open economies but emerging countries. Their top five trading partners are China, Brazil, Argentina, Chile and Russia[3]. In addition, Paraguay is a full member of MERCOSUR, South American trade bloc comprising all emerging economies in the

[1] Agriculture includes all crops and livestock products.

[2] *Agricultural goods* include selected raw and processed agriculture exports that are typically used in the food industry.

[3] Percentages are averages for the period 2007-2017. Calculations by analysts from the International Economics Department, Central Bank of Paraguay .

Figure 1: Composition of annual exports (%, 5 year rolling average)



Notes: Data from Central Bank of Paraguay. Selected raw agricultural goods include cereals, soybeans, sunflower seeds, sesame seeds and sugar. Processed agricultural goods include all types of meat and vegetable oils and meals

region[4].

Fifth and final, the paraguayan financial system is not as linked with the global financial system as other emerging countries. Paraguayan banks are largely funded through deposits and capital. Foreign ownership of deposits is small and foreign equity (mainly from Brazil) represents only 2.5 percent of system assets. At the same time, foreign investors do not hold domestically-issued government bonds and most portfolio inflows to the country are linked to the issuance of sovereign bonds in international markets which started in 2013. Since financial linkages between Paraguay and the rest of the world are limited, trade channels may be the main source of vulnerability to external shocks (International Monetary Fund, 2016).

These joint characteristics would imply that the domestic economy may be highly exposed to fluctuations in prices of key commodity exports, international market of sovereign bonds and foreign demand.

1.2 A first look at the relationship foreign shocks and CPI

Foreign shocks may also be transmitted to the Consumer Price Index (CPI) through the supply of raw inputs to the food industry sector. As food composes 31% of the

[4]The MERCOSUR is a South American trade bloc established by the Treaty of Asuncion in 1991. Full members of the treaty are Argentina, Brazil, Paraguay and Uruguay. Associate countries are Bolivia, Chile, Peru, Colombia, Ecuador and Suriname

representative consumption basket[5] and around 92% of these food products is produced domestically, we would expect a significant role of these shocks in the paraguayan CPI.

Indeed, two events described in International Monetary Fund (2008, 2016) are evidence that there is a relationship between commodity prices fluctuations and domestic inflation. An increase (decrease) in commodity prices tends to put upward (downward) pressure in total CPI, mainly through the food component.

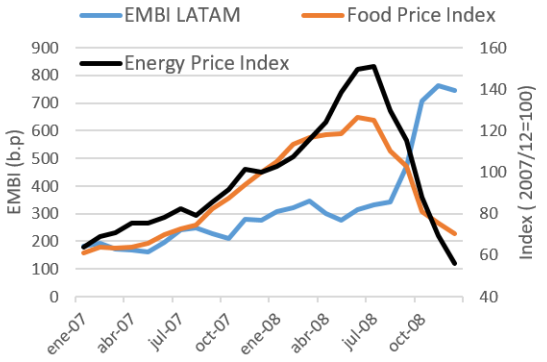
Higher prices of commodity exports and the record agriculture production in 2007 led to a significant rise in exports and domestic currency appreciation against the U.S. dollar. Figure 2 shows that the continued strengthening of commodity prices and the external position in the first half of 2008 appreciated even further the domestic currency. Core inflation rose, particularly driven by inflation in food products and non tradables. On the other hand, prices of non-food tradables remained relatively stable as these are mainly imported goods. In response to inflationary pressures, the Central Bank adopted a tightening stance in the second half of 2007 and tightened further in March 2008.

The second event was observed during the three first quarters of 2015. The paraguayan economy was facing adverse external conditions as the commodity super-cycle was ending and regional growth outlook deteriorating. Figure 3 illustrates that paraguayan food exports (i.e raw and processed agricultural goods) decreased substantially and that the Guarani depreciated significantly against the U.S. dollar. As the exchange rate pass-through to the imported component of aggregate prices was compensated by the initial decrease in food prices and muted response of non tradables, core inflation remained subdued during most of 2015. The monetary policy rate remained unchanged as GDP was growing below its potential level and inflation pressures remained contained.

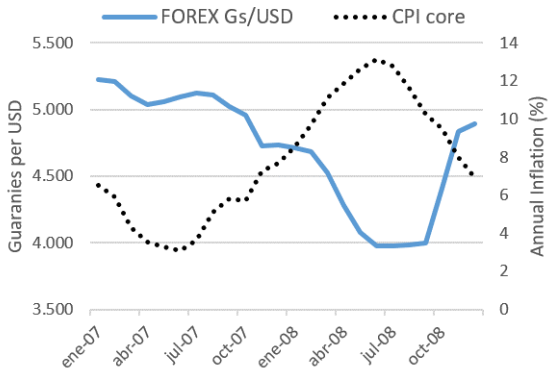
[5]Basket excludes fruits, vegetables and goods with regulated prices and base year is 2007

Figure 2: Rising commodity prices (period 2007-2008)

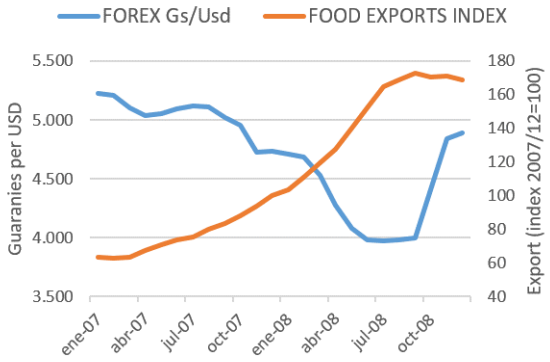
(a) Regional risk and commodity prices



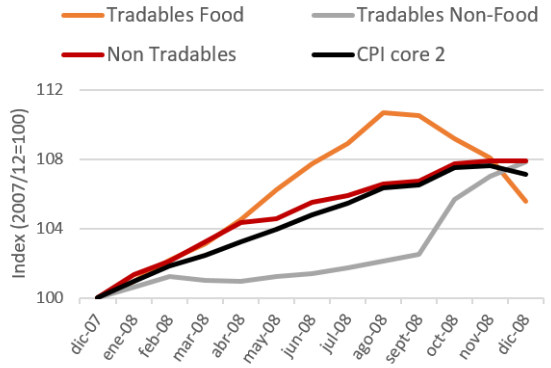
(b) Guarani appreciation and inflation



(c) Rising food exports



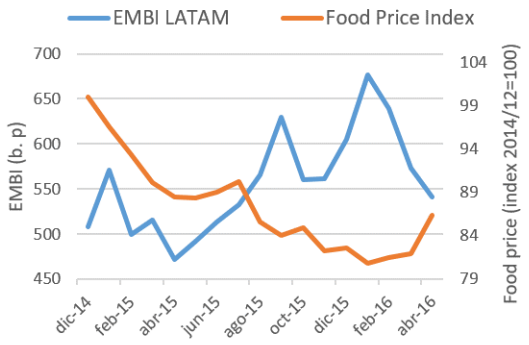
(d) Inflation by main components



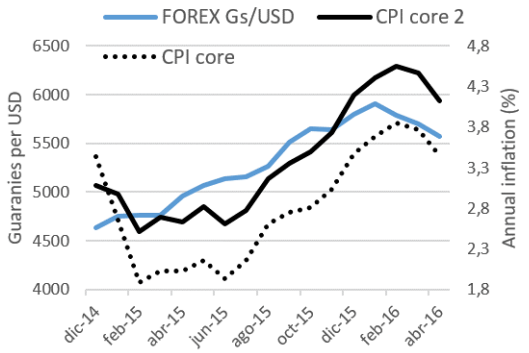
Notes: Data from Central Bank of Paraguay, Bloomberg and World Bank. **EMBI LATAM** is JP Morgan's EMBI Global index for Latin America (basis points). **Food Price Index** is a monthly Index based on nominal US dollars, 2007=100. It is a weighted average of selected commodity price indexes from the World Bank Commodity Price Data (The Pink Sheet). Weights are those published by the WB based on 2002-04 developing countries' export values. Items selected are: cereals (rice, wheat, maize and barley), soybeans, soybean oil, soybean meal, sugar and beef. These goods represent 82% of (raw and processed) agricultural exports from Paraguay. **Energy Price Index** comprises Coal, Crude Oil and Natural Gas. Index from World Bank Commodity Price Data (The Pink Sheet). **Food exports index** is total (raw and processed) agricultural exports in USD (FOB) expressed as index taking 2007/12=100. **FOREX Gs/USD** is the nominal exchange rate expressed in Guaranies per U.S. dollar. **CPI Core** is headline CPI excluding fruits and vegetables. **CPI Core 2** is headline CPI excluding fruits, vegetables and goods with regulated prices. This index is decomposed in **Tradables Food CPI**, **Tradables Non-Food CPI** and **Non Tradables CPI**.

Figure 3: End of the commodity super-cycle (2015-2016)

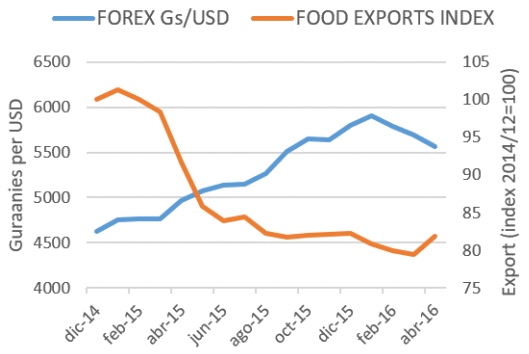
(a) Regional risk and commodity prices



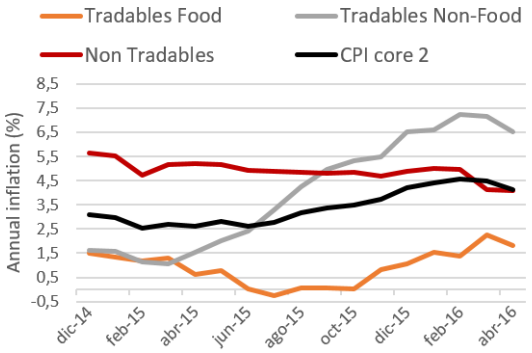
(b) Guarani depreciation and inflation



(c) Decrease in food exports



(d) Inflation by main components



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2 Variable choice in VARs containing aggregate prices

This section applies a bayesian methodology developed by Jarocinski and Mackowiak (2016) and inform us on the relative relevance of international variables when estimating a VAR model containing aggregate prices of Paraguay[6].

The methodology relies on the idea of Granger-causal-priority which is related with the concept of Granger-noncausality. The authors describe their methodology using the example of a researcher that wants to predict y_i with a reduced-form VAR or to cumpute impulse responses of y_i to structural shocks using a SVAR. The researcher has data on a set of variables of interest including y_i and many others y_J with no knowledge on whether to include in her model or not. The questions she might be interested in answering are (i) Does y_J helps predict y_i and should therefore be included in the VAR? and (ii) Does y_J belong in a VAR to be used to compute impulse responses of y_i to structural shocks?.

To answer these questions, one needs to think in terms of the Granger-causal-priority concept, explained and defined formally in their paper. If y_i is Granger-causally prior (GCP hereafter) to y_J, the forecasts of y_i obtained from a VAR with all variables y are equal to the forecasts of y_i obtained from a smaller model that omits y_J. In this sense, y_J doesn't help predict y_i and can be excluded from the VAR model. In addition, If y_i is GCP to y_J and an additional assumption holds, the impulse responses of y_i to a structural shock of interest obtained from a VAR with all variables y is equal to the impulse response of y_i to that shock obtained from a smaller model that omits y_J. In this sense, y_J does not belong in the VAR to be used to compute impulse responses of y_i to structural shocks.

As in finite samples we cannot know if y_i is GCP to y_J, so the authors rely on the bayesian approach to inference and derive closed form expression for the posterior probability that y_i is GCP to y_J. See more technical details in their paper.

In this section we are interested in first asking which variables from a broad list of potential ones may help predict CPI main components such as CPI food tradables , CPI non-food tradables and CPI non tradables. Next, we ask which variables to include in a var containing CPI, domestic output, the nominal interest rate and nominal exchange rate.

We put together a dataset with 24 variables. Table 4 lists all variables.

In the first application, the variables of interest are three: CPI food tradables, CPI non-food tradables and CPI non tradables. The other variables are the remaining 20 (excluding total CPI) and are classified into 5 categories: other domestic variables, exchange rates, foreign activity in MERCOSUR countries, international finance, international prices. The sample contains monthly data from december 2007 to october 2017[7]. All variables enter

[6]I gratefully acknowledge Marek Jarocinski for helping me with the Matlab codes.

[7]We restrict the sample to june 2017 as we couldn't find an updated series of pfood from the IFS-IMF

in logs except interest rates and spreads. I use the Minnesota prior and set the model to 1 lag for estimation[8].

Table 2 reports the posterior probability that y_i (CPI food tradables, CPI non-food tradables and CPI non tradables) is not GCP to a given $y_j \in y_J$. The highest ranked variables that help predict our variables of interest are shaded. Financial risk mesures ($rrisk$, $rrisk^{BR}$, $rrisk^{AR}$), nominal exchange rate with USD (s_{usd}), nominal exchange rate with the brazilian real (s_{real}), energy prices (Energy) and vegetable oils price index (Veg Oils) are the most relevant variables that help predict aggregate prices.

In the second application, the variables of interest are four: CPI total (cpit), domestic aggregate activity (y), the nominal interest rate (IRMP) and nominal exchange rate with the U.S. dollar (s_{usd}). The other variables are 14 and are classified into 4 categories: other domestic variables, foreign activity in MERCOSUR countries, international finance and international prices. As before, the main sample contains monthly data from december 2007 to october 2017.

Table 3 reports the posterior probability that y_i (cpit,y, IRMP and s_{usd}) is not GCP to a given $y_j \in y_J$. The highest ranked variables that help predict our variables of interest are shaded. Financial risk mesures ($rrisk$, $rrisk^{BR}$, $rrisk^{AR}$), vegetable oils price index (Veg Oils) and monetary aggregates (BM and M1) are the most relevant variables..

Putting together what both applications find, the main message is that when we are studying fluctuations in aggregate prices in Paraguay, it is important to include foreign variables such as those reflecting risk and commodity prices. The next section takes into account these findings when defining a SVAR model including typical variables used in neo-keynesian models; namely total CPI, nominal interest rate and domestic aggregate activity.

[8]The methodology doesn't include the possibility of block exogeneity or overidentified SVARs which are typically asummed in models for small open economies. Therefore, I restrict the estimation to 1 lag. Results are robust when estimating model with 6 lags

Table 1: Variable names and sources

Variable	Description	Transf.	Source
	Aggregate domestic prices		
cpitf	CPI food tradables (excludes fruits, vegetables and goods with regulated prices)	log	BCP
cpitnf	CPI non food tradables (excludes goods with regulated prices)	log	BCP
cpin	CPI non tradables (excludes goods with regulated prices)	log	BCP
cpit	CPI total (excludes fruits, vegetables and goods with regulated prices)	log	BCP
	Other domestic variables		
y	Monthly index of economic activity excluding binationals (IMAEP)	log	BCP
$credit_{cons}$	Total consumption credit by banks and financial intermediaries (monthly indices based on PY Guaranies)	log	BCP
$credit_{tot}$	Bank credit to private sector (monthly indices based on PY Guaranies)	log	BCP
IRMP	Nominal interest rate of BCP instruments (weighted average, %)	Div. 100	BCP
BM	Monetary base (M0 + Banks Reserves)	log	BCP
M1	M0 plus the amount of demand deposits and other checkable deposits	log	BCP
	Exchange rates		
s_{usd}	Nominal exchange rate with USD (Guaranies per USD)	log	BCP
s_{real}	Nominal exchange rate with brazilian real (Guaranies per real)	log	BCP
s_{euro}	Nominal exchange rate with Euro (Guaranies per euro)	log	BCP
s_{peso}	Nominal exchange rate with argentinian peso (Guaranies per peso)	log	BCP
	Foreign activity MERCOSUR		
y^{AR}	Aggregate activity in Argentina (EMAE)	log	INDEC
y^{BR}	Aggregate activity in Brazil (BZEAMOM Index)	log	Bloomberg
	International finance		
rrisk	Regional risk (JP MORGAN EMBIG Index for Latam, basis points)	Div. 10000	Bloomberg
$rrisk^{AR}$	Argentina risk measure (JP MORGAN EMBIG Index for Argentina, basis points)	Div. 10000	Bloomberg
$rrisk^{BR}$	Brazil risk measure (JP MORGAN EMBIG Index for Brazil, basis points)	Div. 10000	Bloomberg
TB3MS	3-Month Treasury Bill: Secondary Market Rate (%)	Div. 100	FRED
	International prices		
Veg Oils	Vegetable Oils and Meals Price index (includes soybeans, soybean oil and meal)	log	World Bank Commodity Price Data
Grains	Grains Price Index (includes rice, wheat, maize and barley)	log	
Energy	Energy Price Index (includes crude oil, natural gas,coal)	log	
Meat price Index	Meat Price Index (includes bovine, chicken, pig and ovine meat products)	log	FAO

Table 2: Posterior probability that CPI food tradables, CPI non food tradables, and CPI non tradables are Granger-causally-prior to a variable.

Category	Variable	1 - p(yI GCP yj)	Rank
Domestic variables	y	0.0717	17
	$credit_{cons}$	0.4768	11
	$credit_{tot}$	0.3234	13
	IRMP	0.2670	14
	BM	0.5082	10
	M1	0.1811	15
Exchange rates	s_{peso}	0.1611	16
	s_{real}	0.8673	6
	s_{usd}	0.9980	2
	s_{euro}	0.5789	9
Foreign activity MERCOSUR	y^{BR}	0.0005	19
	y^{AR}	0.0000	20
International finance	rrisk	1.0000	1
	$rrisk^{BR}$	0.9515	4
	$rrisk^{AR}$	0.9233	5
	TB3MS	0.0025	18
International prices	Veg Oils	0.8398	7
	Grains	0.4205	12
	Meat price Index	0.6372	8
	Energy	0.9596	3

Table 3: Posterior probability that nominal interest rate, nominal exchange rate with the US, domestic aggregate activity and total CPI are Granger-causally-prior to a variable.

Category	Variable	1 - p(yI GCP yj)	Rank
Domestic variables	$credit_{cons}$	0.2324	9
	$credit_{tot}$	0.1763	10
	BM	0.9481	5
	M1	0.8095	6
Foreign activity MERCOSUR	y^{BR}	0.0000	13
	y^{AR}	0.0000	12
International finance	rrisk	1.0000	1
	$rrisk^{BR}$	0.9937	4
	$rrisk^{AR}$	0.9992	2
	TB3MS	0.0000	14
International prices	Veg Oils	0.9959	3
	Grains	0.0878	11
	Meat price Index	0.7875	7
	Energy	0.7269	8

3 Empirical analysis

The goal of this section is to lay out the empirical model and to identify shocks to commodity prices and regional risk. Let us begin with the general specification:

$$y_t'A = \sum_{t=1}^{p} Y_{t-l}'A_l + z_t'D + \epsilon_t' \quad for\ t = 1, \ldots, T, \tag{1}$$

where y_t is an $n \times 1$ column vector of endogenous variables at time t, z_t is and $h \times 1$ column vector of exogenous variables at time t, p is the lag length and T is the sample size. Matrices A and A_l have dimension $n \times n$, D is an $h \times n$ parameter matrix for exogenous variables, ϵ_t is and $n \times 1$ column vector of structural disturbances at time t.

Structural disturbances have a Gaussian distribution with:

$$\begin{aligned} E(\epsilon_t \mid y_1, \ldots, y_{t-1}, z_1, \ldots, z_T) &= 0_{n\times 1} \\ E(\epsilon_t\epsilon_t' \mid y_1, \ldots, y_{t-1}, z_1, \ldots, z_T) &= I_{n\times n} \end{aligned} \tag{2}$$

The structural disturbances in (2) are normalized to have an identity covariance matrix. Right multiplying the structural form (1) by A^{-1} yields the usual representation of a reduced-form VAR

$$y_t' = \sum_{t=1}^{p} Y_{t-l}'B_l + z_t'B_0 + u_t' \quad for\ t = 1, \ldots, T, \tag{3}$$

The previous equation implies a relationship between the reduced form covariance matrix and the matrix A from the structural form:

$$\Sigma = (AA')^{-1} \tag{4}$$

Let $y_t' = [y_{1t}', y_{2t}']$, where y_{1t} be the vector of international variables and y_{2t} be the vector of domestic variables. The set of variables considered in the model are:

$$\begin{aligned} y_1 &= \begin{bmatrix} wpx & rrisk \end{bmatrix}' \\ y_2 &= \begin{bmatrix} y & cpif & cpit & i & s \end{bmatrix}' \end{aligned}$$

where wpx is a price index for key commodity exports, $rrisk$ is a measure of regional risk, y is domestic output, $cpif$ is food CPI, $cpit$ is total CPI, i is the nominal interest rate, s is the exchange rate. Notice we also include a narrower measure of CPI that is expected to be more tightly linked with commodity prices, food CPI. Table below describes the variables used and sources.

Table 4: Variable names and sources

Variable	Description	Source
wpx	Food Price Index (includes cereals, soybeans, soybean oil, soybean meal, sugar and beef)	BCP and World Bank
$rrisk$	Regional risk (LATAM EMBIG basis points)	Bloomberg
y	Domestic Aggregate activity (IMAEP index excluding binationals)	BCP
$CPIf$	CPI food tradables (excludes fruits, vegetables and goods with regulated prices)	BCP
$CPIt$	CPI total (excludes fruits, vegetables and goods with regulated prices)	BCP
i	Nominal interest rate of BCP instruments (weighted average)	BCP
s	Nominal exchange rate (Guaranies per U.S. dollar)	BCP

Notes: BCP stands for Central Bank of Paraguay.

All variables are monthly and output series is seasonally adjusted. Most series enter the structural VAR in log terms, except $rrisk$ and i that are expresed in percentage points. The system has 7 variables so the reduced form covariance matrix in (4) requires $7 \times 6/2 = 21$ for exact identification.

3.1 Identification strategy

As it is typical in the case of small open economies, the assumed processes for international variables excludes domestic variables at all lags. In other words, the international block of variables satisfies the block exogeneity assumption.

All identifying restrictions on the contemporaneous matrix A are summarized in Table (5). Dependent variables in the system of equations are represented in the columns. If cell (i, j) says free, row variable i influences contemporaneously variable j and this coefficient is estimated. If cell (i, j) says 0, row variable i doesn't affect contemporaneously variable j and this coefficient is restricted to 0. The identification assumptions impose more restrictions than needed and the model is over identified.

Following papers in the SVAR literature, we assume output y is predetermined and the most exogenous variable within the domestic block of variables. Both price indexes can be contemporaneously affected by exogenous shocks to domestic activity and to themselves. Here, we are consistent with the empirical evidence that the exchange rate pass-through effect on aggregate prices is not instantaneous; see, e.g., Engel (2002) and Burstein et al. (2002). Furthermore, we assume an exogenous change in nominal interest rates won't

have an immediate effect on aggregate prices.

Table 5: Identifying restrictions

	wpf	$rrisk$	y	$cpif$	$cpit$	$i0$	s
wpf	free	free	0	0	0	free	free
$rrisk$	0	free	0	0	0	free	free
y	0	0	free	free	free	0	free
$cpift$	0	0	0	free	free	0	free
$cpit$	0	0	0	free	free	0	free
i	0	0	0	0	0	free	free
s	0	0	0	0	0	0	free

The Central Bank of Paraguay adopted the inflation targeting regime in 2011 and started using the monetary policy rate as official policy instrument in 2013(Cuevas, 2016). Prior to 2011, the monetary policy framework was focused on monetary aggregates. Since our sample starts in december 2007, we can't properly use the policy rate as i. Instead we use the weighted average of nominal interest rates of instruments that the Central Bank uses to conduct open market operations (*Letras de Regulacion Monetaria*). Unfortunately, we can't fully and precisely associate i with the monetary policy instrument as we can't neglect the presence of market forces behind the nominal interest rate we use in the model.

Even though we are not able to identify monetary policy shocks in this paper, we impose the sensible assumption that the equilibrium value of i is mostly based on agents' expectations of future economic conditions. We assume bankers and the monetary policy authority tend to have immediate information about commodity prices and regional risk to base their expectations on; but information on output, aggregate prices and nominal exchange rates arrive with some lag.

3.2 Estimating the model: Wagonner and Zha's algorithm.

To estimate this model, bayesian techniques are used. In their 2003 paper, Wagonner and Zha provided a two step Gibbs sampling procedure that is readily applicable to over identified models that also include restrictions on lagged coefficients. In other words, their method allows non recursive structures in the contemporaneous matrix and the use of block exogeneity restrictions. It has proven to be appropriate for small open economy applications because it improves efficiency and provides better economic interpretations of impulse responses that appeared distorted under conventional techniques.

Once defined the restrictions, we are ready to implement the algorithm. We use the Minnesota prior and set the model to 6 lags for estimation[9]. After generating a chain of 1100 MC draws of both $A0$ and F coefficients, I burn 100 draws[10]. We conduct impulse response analysis and variance decomposition in the next subsections.

4 Estimation results

In this section I discuss how and by how much regional risk shocks and commodity prices shocks affect domestic variables such as output, Food CPI, Total CPI, the nominal interest rate and the exchange rate with the USD.

4.1 Impulse Responses

The estimated impulse responses following a one standard deviation disturbance in food prices (wpx) are displayed in Figure 9. The response horizon, in months, is given in the horizontal axis. The solid lines are the median responses and the shaded areas contain the 90% credible sets.

A one standard deviation increase in food prices (i.e 6%) causes regional risk to decrease on impact and stay significantly below zero for 8 months. This is consistent with the empirical literature finding a strong negative correlation between commodity prices and external debt spreads for emerging countries; see Fernandez et al. (2018), Ibarlucia et al. (2013) and Shousha (2016).

Regarding domestic aggregate prices, an increase in food prices causes a fast increase in both food cpi and total cpi that peak after 7 months and then gradually bounce back to become insignificant after 15 months.

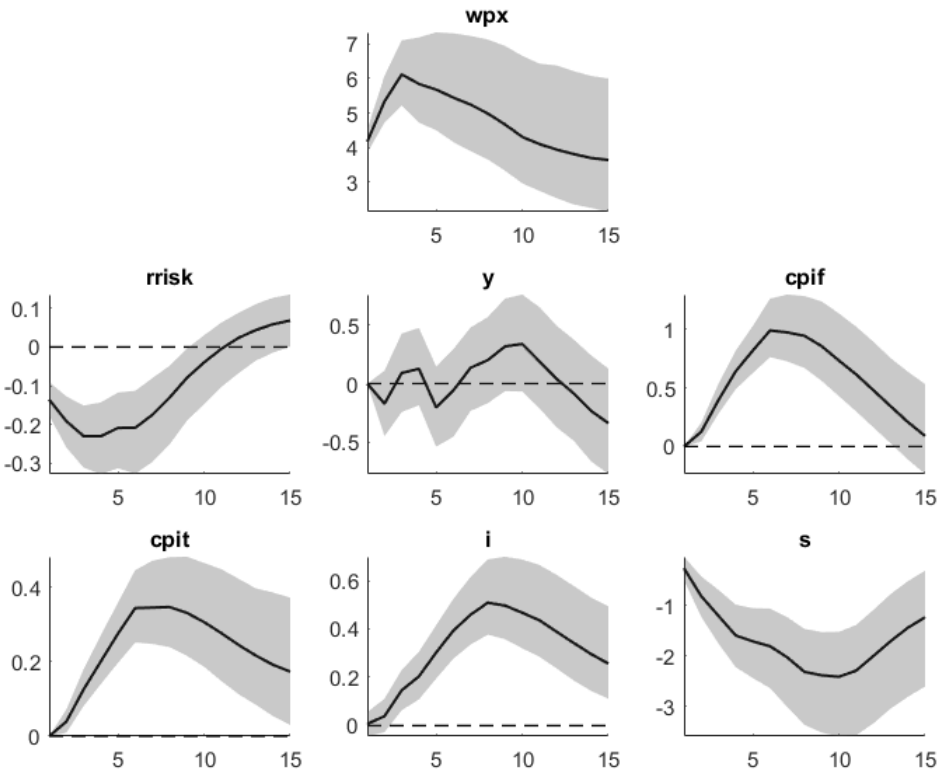
The nominal interest rate increases, reaching its peak at approximately 10 months after the shock, and stays significantly different than zero for a period longer than 15 months. We can interpret the increase in the nominal interest rate coming from policy makers reacting positively to information about expected inflation or as market outcome mirroring the fisher hypothesis[11]. Domestic currency appreciates relative to the USD on impact, reaches maximum appreciation at around 10 months and stays significant for a period longer than 15 months. The response of our measure of output is insignificant.

[9] Both AIC and BIC suggest p to 12 lags but we restrict it considering the small sample and the number of endogenous variables

[10] Convergence diagnostics statistics indicate convergence in means for each individual chain of coefficients. Results available upon request.

[11] The Fisher hypothesis is the proposition by Irving Fisher implying that real interest rate movements are uncorrelated with movements in the inflation rate. In other words, a change in market rates of interest is associated approximately point for point with a change in expected rate of inflation

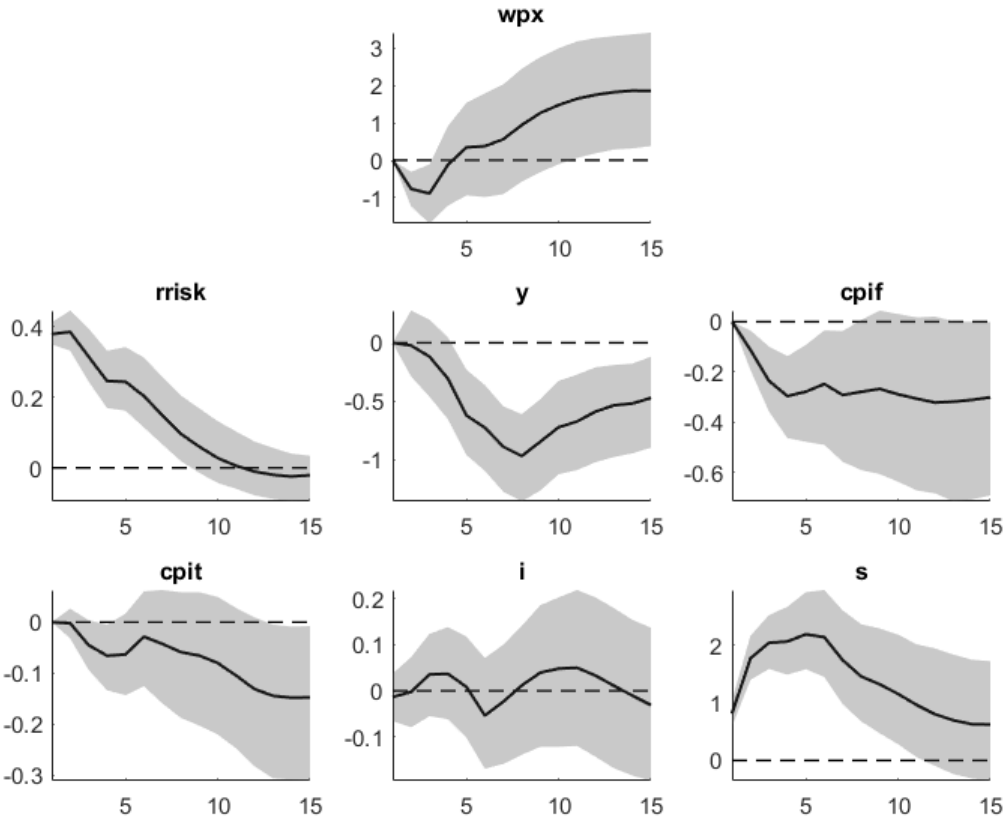
Figure 4: Impulse responses to a one standard deviation (%) shock in Food prices (wpx): median, 10th and 90th percentiles of the posterior distribution



Notes: Black line is median response and shaded area is 90% credible set. All vertical axes are in %.

Figure 5 displays the responses of all variables included in the VAR system to a one standard deviation increase in regional risk (0.4% or 25 basis points). An increase in regional risk causes food prices to decrease after a month but this effect quickly becomes insignificant. The shock in regional risk causes a significant decrease in food cpi within 5 months after the shock. There is no significant effect on total CPI and the nominal interest rate. Domestic currency depreciates relative to the USD on impact, staying significant for around 10 months. Output decreases significantly 5 months after the shock and stays low for a period longer than 15 months. The simultaneous decrease in food CPI and a nominal depreciation may seem counter-intuitive. However, we expect that the exchange rate pass-through effect would tend to be weaker particularly in the short term, since only around 10% of food CPI is imported.

Figure 5: Impulse responses to a one standard deviation shock (%) in EMBI Latam (*rrisk*): median, 10th and 90th percentiles of the posterior distribution

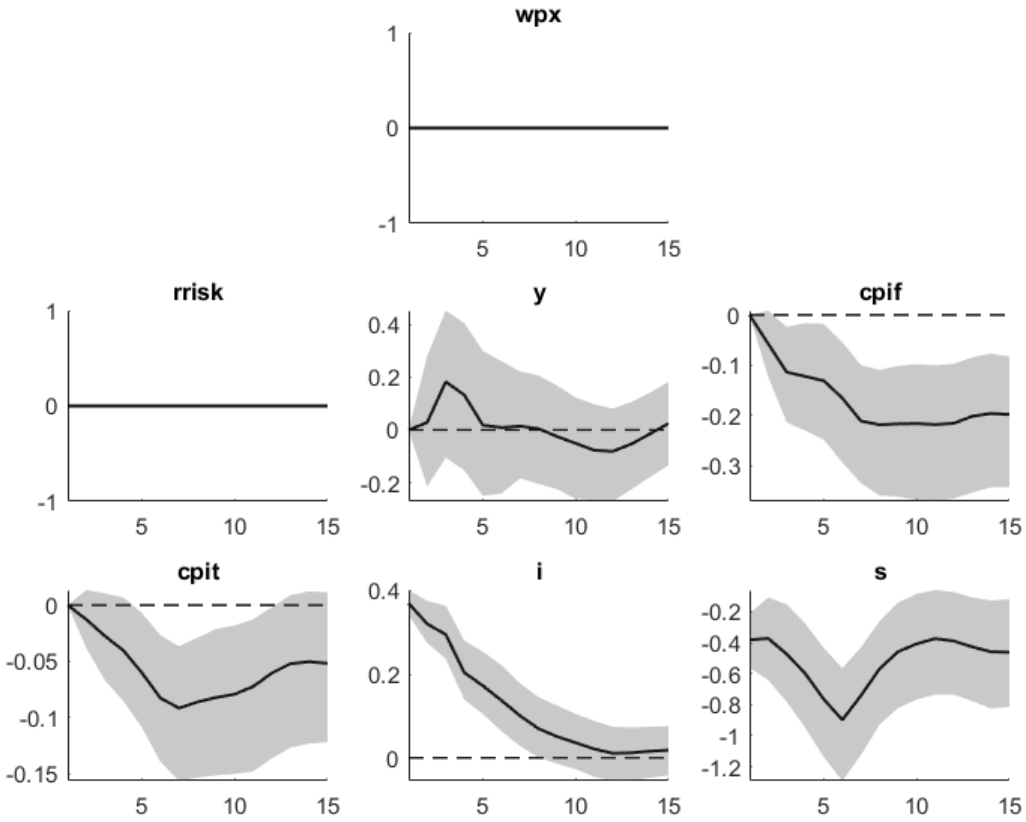


Notes: Black line is median response and shaded area is 90% credible set. All vertical axes are in %.

Since we include the nominal interest rate in the VAR system and as argued earlier it is a partial measure capturing monetary policy shocks, we present impulse responses due to a "contractionary shock" in Figure 6. After a one standard deviation increase in the nominal interest rate (0.4% or 25 basis points), food CPI decrease significantly after two months and stays low for a period longer than 15 months. Total CPI also decrease significantly but after a longer lag (6 months). Unlike food CPI, the effect on total CPI becomes insignificant after 12 months. Nominal exchange rate appreciates on impact, reaching maximum appreciation within 7 months and thereafter gradually depreciates to baseline. This is consistent with the overshooting hypothesis in Dornbusch (1976)[12].

[12] An increase in i makes domestic assets more attractive to investors. Following the uncovered interest-rate parity (UIP), the market expects a depreciation in the exchange rate. But in the long run PPP holds and the exchange rate must appreciate overall. The exchange rate must therefore appreciate so much after the shock that it overshoots its long-run equilibrium level and depreciates thereafter.

Figure 6: Impulse responses to a one standard deviation shock (%) in the interest rate (i): median, 10th and 90th percentiles of the posterior distribution



Notes: Black line is median response and shaded area is 90% credible set. All vertical axes are in %.

4.2 Variance decomposition

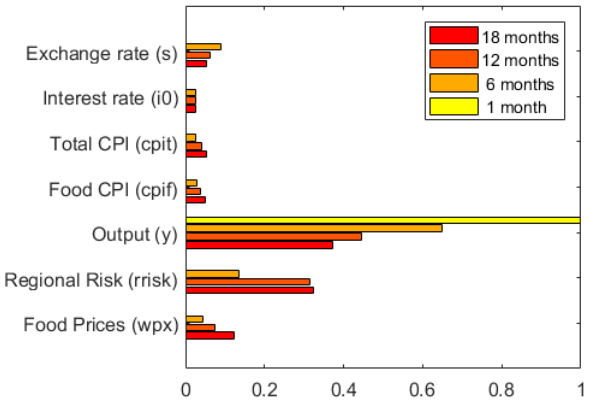
Figures 4 to 8 display the variance decomposition of domestic variables contained in the VAR system at different horizons. For the purpose of the present discussion, I associate short term fluctuations with the variance of the forecasting error at the horizon of 6 months. The corresponding percentage contribution to short term fluctuations is based on mean estimates. For the 90% credible set see Tables in Appendix.

According to my estimates of the VAR system, innovations in food prices explain 4% of short term movements in aggregate activity, 50% of Food CPI, 37% of Total CPI, 32% of interest rates and 24.5% of exchange rates.

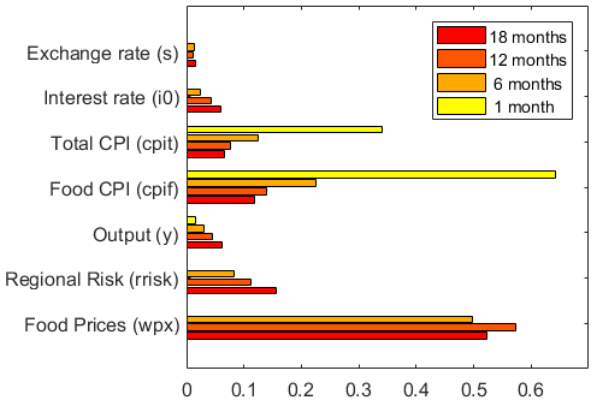
Regional risk shocks account for approximately 13.4% of short term movements in output, 8.2% of Food CPI, 3.5% of Total CPI and interest rate fluctuations and aggregate activity. In the case of the exchange rate, innovations in regional risk explain around 47% of short term movements.

Figure 7: Variance decomposition at various horizons

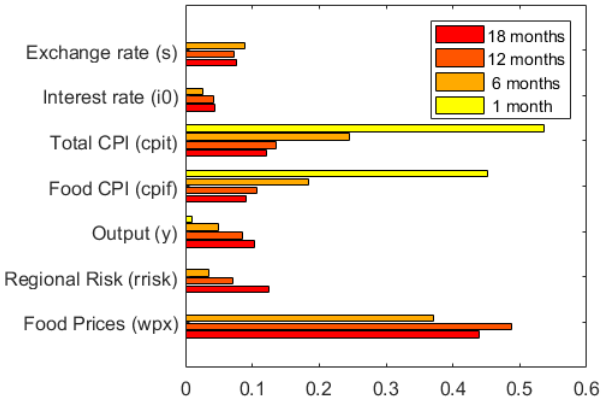
(a) Domestic output (y)



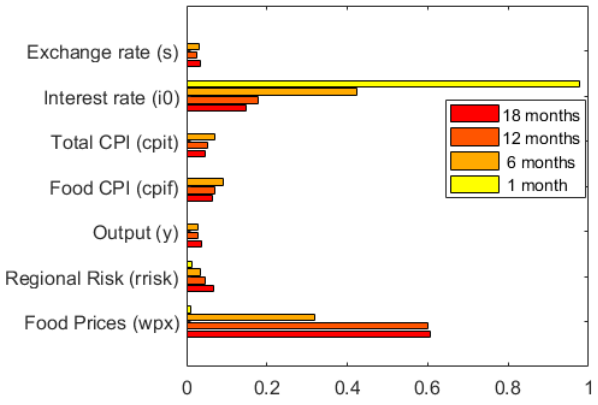
(b) Food CPI (cpif)



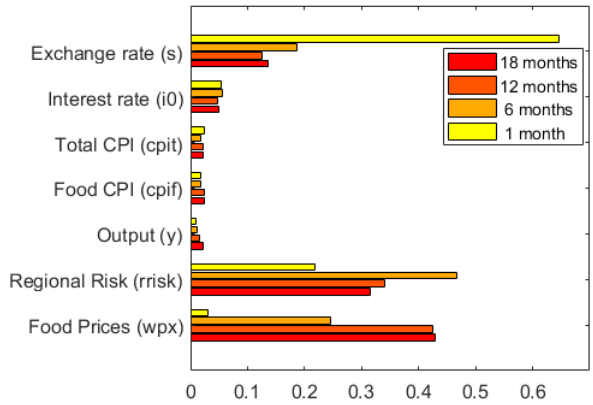
(c) Total cpi (cpit)



(d) Nominal interest rate (i)



(e) Exchange rate (s)



4.3 The role of regional risk in the transmission of food price shocks

As shocks in commodity prices play an important role in regional risk, the natural question to ask in this context is to what extent the responsiveness of regional spreads to commodity prices contributes to short term fluctuations in domestic variables.

This question is addressed by doing a counterfactual exercise. Keeping fixed the model estimates, I modify the VAR system such that regional risk does not depend on commodity prices neither contemporaneously or at lags. Specifically the regional risk equation is modified by setting to zero coefficients on wpx_{t-i} for $i \in [1, 6]$. I then compute the impulse response functions and perform variance decomposition based on the modified VAR system.

The variance decomposition of all domestic variables are shown in Figure 8. When I shut off the response of regional risk to commodity prices, the variances of these domestic variables explained by commodity prices shocks decrease. While for domestic prices the decreases relative to the unrestricted estimates are by around 10 percentage points on average but not significantly different, for exchange rates is around 20 percentage points and significantly lower[13]. No significant changes are found in the case of aggregate activity and interest rates.

The impulse responses following a one standard deviation increase in food prices (wpx) when I shut off the endogenous response of regional risk are shown in Figure 9. The dynamics of food cpi, total cpi and interest rate are quite similar to the unrestricted analysis. The main significant difference is that when when I shut off the regional risk channel, domestic currency is not affected on impact anymore and only appreciates later than 5 months after the shock. Finally, the median response of output remains insignificant but stays negative unlike in the unrestricted analysis.

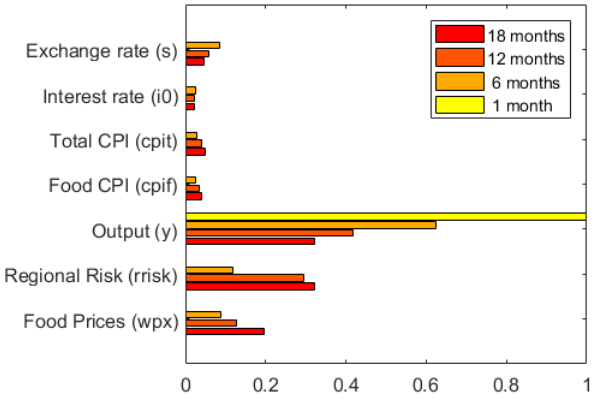
While I can't conclude that regional risk is an important transmission mechanism for commodity price shocks in the paraguayan economy[14], this analysis motivates the inclusion of a spread process when defining a neokeynesian model for the paraguayan economy to study commodity price shocks and monetary policy implications.

[13] See Table with credible sets in Appendix.

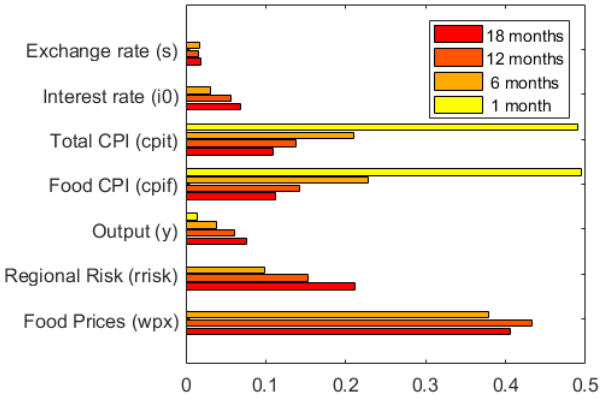
[14] This exercise is subject to Lucas (1976) critique. A more satisfactory approach would be to use a theoretical model economy in which private decisions change when there are shocks to the regional risk process.

Figure 8: Variance decomposition at various horizons (counterfactual)

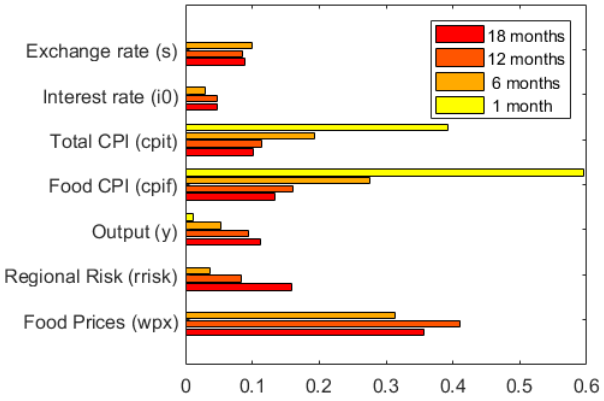
(a) Domestic output (y)



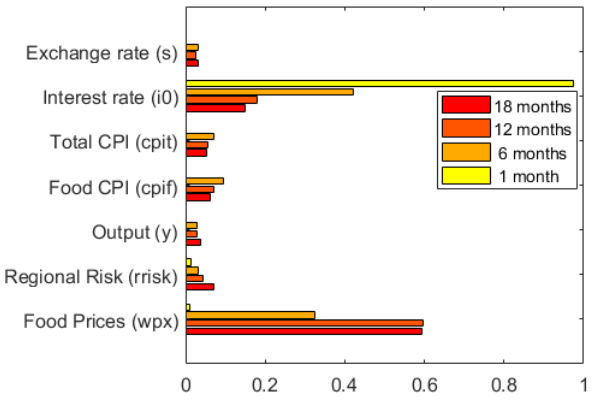
(b) Food CPI (cpif)



(c) Total cpi (cpit)



(d) Nominal interest rate (i)



(e) Exchange rate (s)

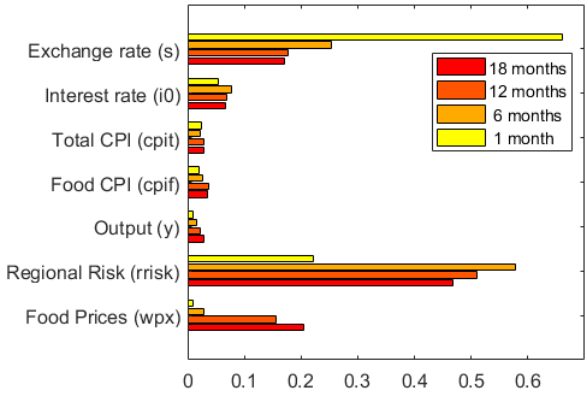
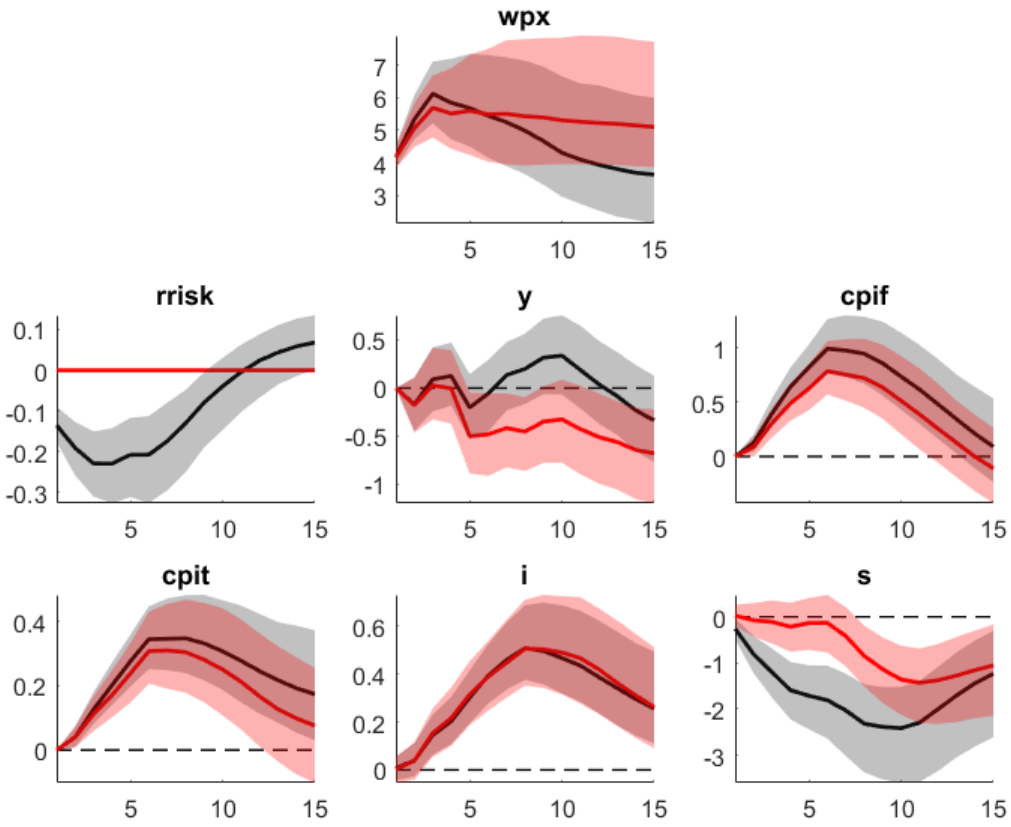


Figure 9: Impulse responses to a one standard deviation (%) shock in Food prices *wpx* (counterfactual exercise)



Notes: Continuous lines are median responses. Red line is median response when there is no regional risk channel and black line is median response when there is regional risk channel. Shaded areas are 90% credible sets. Grey area corresponds to unrestricted estimation and red area represents that of the counterfactual exercise. All vertical axes are in %.

5 Final Remarks

I apply the bayesian methodology developed by Jarocinski and Mackowiak (2016) to Paraguayan data and find that foreign variables such as those reflecting risk and commodity prices are highly relevant in the prediction of aggregate prices. This is a first important result that may guide models to forecast inflation used in the Central Bank of Paraguay.

Next, I define a SVAR model that includes typical variables used in neo-keynesian models; namely total CPI, nominal interest rate and domestic aggregate activity. Taking into account earlier findings, we add regional risk and commodity prices.

My estimates find that exogenous shocks in prices of key commodity exports and, at a lower extent, in regional risk are important drivers of aggregate fluctuations in Paraguay. Commodity prices explain a substantial percentage of movements in almost all domestic variables, particularly CPI and its food component. On the other hand, regional risk have a very important role in the exchange rate, as it accounts for approximately half of its short term movements.

Finally, the counterfactual exercise suggests that regional risk have a role in the transmission of commodity price shocks to the domestic economy. However, results should be taken carefully as it is subject to Lucas' critique. This preliminary analysis motivates the inclusion of a spread process when defining a neokeynesian model for the paraguayan economy. This task is left for future research.

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Table 6: Variance Decomposition 6 month horizon

	Food Prices (wpx)	Regional Risk (rrisk)	Output (y)	Food CPI (cpif)	Total CPI (cpit)	Interest rate (i0)	Exchange rate (s)
Food Prices (wpx)	0.973	0.027	0.000	0.000	0.000	0.000	0.000
	(0.946-0.993)	(0.007-0.054)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Regional Risk (rrisk)	0.314	0.686	0.000	0.000	0.000	0.000	0.000
	(0.160-0.476)	(0.524-0.840)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Output (y)	0.044	0.134	0.648	0.030	0.027	0.027	0.090
	(0.013-0.082)	(0.046-0.235)	(0.546-0.750)	(0.008-0.060)	(0.008-0.054)	(0.007-0.056)	(0.031-0.157)
Food CPI (cpif)	0.498	0.082	0.031	0.226	0.125	0.023	0.013
	(0.360-0.632)	(0.016-0.169)	(0.014-0.053)	(0.042-0.395)	(0.008-0.304)	(0.004-0.050)	(0.002-0.030)
Total CPI (cpit)	0.371	0.035	0.049	0.184	0.246	0.027	0.088
	(0.224-0.513)	(0.005-0.086)	(0.014-0.096)	(0.016-0.408)	(0.029-0.443)	(0.004-0.056)	(0.037-0.143)
Interest rate (i0)	0.319	0.035	0.029	0.090	0.071	0.423	0.033
	(0.166-0.479)	(0.008-0.073)	(0.008-0.061)	(0.010-0.189)	(0.006-0.167)	(0.313-0.543)	(0.006-0.069)
Exchange rate (s)	0.245	0.466	0.011	0.017	0.018	0.056	0.187
	(0.104-0.394)	(0.307-0.625)	(0.002-0.024)	(0.003-0.040)	(0.004-0.037)	(0.019-0.100)	(0.119-0.266)

Table 7: Variance Decomposition 12 month horizon

	Food Prices (wpx)	Regional Risk (rrisk)	Output (y)	Food CPI (cpif)	Total CPI (cpit)	Interest rate (i0)	Exchange rate (s)
Food Prices (wpx)	0.928	0.072	0.000	0.000	0.000	0.000	0.000
	(0.844-0.987)	(0.013-0.156)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Regional Risk (rrisk)	0.350	0.650	0.000	0.000	0.000	0.000	0.000
	(0.173-0.540)	(0.460-0.827)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Output (y)	0.075	0.313	0.445	0.038	0.042	0.025	0.062
	(0.026-0.148)	(0.158-0.464)	(0.326-0.573)	(0.014-0.066)	(0.015-0.077)	(0.008-0.048)	(0.022-0.111)
Food CPI (cpif)	0.572	0.111	0.046	0.139	0.076	0.044	0.012
	(0.388-0.742)	(0.019-0.239)	(0.017-0.080)	(0.026-0.261)	(0.007-0.180)	(0.011-0.090)	(0.002-0.026)
Total CPI (cpit)	0.488	0.071	0.085	0.106	0.136	0.041	0.072
	(0.293-0.674)	(0.010-0.173)	(0.029-0.152)	(0.011-0.237)	(0.018-0.258)	(0.006-0.093)	(0.024-0.133)
Interest rate (i0)	0.599	0.046	0.027	0.071	0.052	0.178	0.026
	(0.430-0.744)	(0.011-0.101)	(0.010-0.049)	(0.010-0.147)	(0.006-0.117)	(0.103-0.270)	(0.007-0.052)
Exchange rate (s)	0.424	0.341	0.015	0.024	0.022	0.047	0.126
	(0.224-0.617)	(0.170-0.534)	(0.003-0.032)	(0.003-0.055)	(0.004-0.051)	(0.014-0.088)	(0.068-0.194)

Table 8: Variance Decomposition 18 month horizon

	Food Prices (wpx)	Regional Risk (rrisk)	Output (y)	Food CPI (cpif)	Total CPI (cpit)	Interest rate (i0)	Exchange rate (s)
Food Prices (wpx)	0.884	0.116	0.000	0.000	0.000	0.000	0.000
	(0.744-0.983)	(0.017-0.256)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Regional Risk (rrisk)	0.370	0.630	0.000	0.000	0.000	0.000	0.000
	(0.195-0.560)	(0.440-0.805)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Output (y)	0.122	0.322	0.373	0.050	0.054	0.025	0.053
	(0.048-0.214)	(0.156-0.499)	(0.254-0.500)	(0.016-0.096)	(0.016-0.102)	(0.009-0.046)	(0.020-0.093)
Food CPI (cpif)	0.523	0.156	0.063	0.118	0.066	0.059	0.016
	(0.339-0.703)	(0.036-0.332)	(0.021-0.109)	(0.024-0.220)	(0.008-0.152)	(0.016-0.120)	(0.004-0.033)
Total CPI (cpit)	0.440	0.125	0.103	0.091	0.121	0.043	0.077
	(0.222-0.656)	(0.017-0.287)	(0.034-0.184)	(0.014-0.211)	(0.022-0.231)	(0.006-0.100)	(0.024-0.144)
Interest rate (i0)	0.605	0.066	0.038	0.064	0.046	0.147	0.034
	(0.430-0.767)	(0.016-0.140)	(0.013-0.070)	(0.010-0.132)	(0.006-0.100)	(0.074-0.231)	(0.011-0.063)
Exchange rate (s)	0.428	0.314	0.023	0.025	0.023	0.050	0.137
	(0.212-0.638)	(0.143-0.517)	(0.004-0.051)	(0.004-0.060)	(0.004-0.052)	(0.014-0.096)	(0.065-0.219)

Table 9: Variance Decomposition 6 month horizon (counterfactual exercise)

	Food Prices (wpx)	Regional Risk (rrisk)	Output (y)	Food CPI (cpif)	Total CPI (cpit)	Interest rate (i0)	Exchange rate (s)
Food Prices (wpx)	0.975	0.025	0.000	0.000	0.000	0.000	0.000
	(0.948-0.993)	(0.007-0.052)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Regional Risk (rrisk)	0.000	1.000	0.000	0.000	0.000	0.000	0.000
	(0.000-0.000)	(1.000-1.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)	(0.000-0.000)
Output (y)	0.087	0.119	0.623	0.030	0.026	0.026	0.089
	(0.027-0.165)	(0.041-0.205)	(0.494-0.739)	(0.008-0.059)	(0.007-0.052)	(0.006-0.052)	(0.033-0.156)
Food CPI (cpif)	0.376	0.098	0.038	0.239	0.202	0.029	0.018
	(0.213-0.540)	(0.018-0.193)	(0.019-0.063)	(0.026-0.437)	(0.017-0.422)	(0.005-0.062)	(0.003-0.040)
Total CPI (cpit)	0.313	0.035	0.053	0.178	0.292	0.028	0.100
	(0.145-0.480)	(0.005-0.092)	(0.015-0.105)	(0.012-0.430)	(0.039-0.503)	(0.004-0.063)	(0.043-0.171)
Interest rate (i0)	0.325	0.031	0.028	0.071	0.087	0.424	0.035
	(0.145-0.498)	(0.008-0.066)	(0.008-0.058)	(0.006-0.165)	(0.007-0.185)	(0.293-0.560)	(0.007-0.072)
Exchange rate (s)	0.028	0.582	0.014	0.021	0.026	0.076	0.253
	(0.003-0.069)	(0.439-0.713)	(0.003-0.030)	(0.004-0.046)	(0.006-0.057)	(0.027-0.137)	(0.162-0.351)


BANCO CEN
DEL PARAG