Time-varying effects of commodities prices in the Bolivian economy

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Abstract

Bolivia is a small, open and commodity exporter economy, so it has been exposed to different external shocks, mainly to fluctuations in commodity prices. According to the literature, the effects of international commodity prices are not complete and change over time. The objective of this document is to analyze if there is a change in the relationship between commodity prices and the main local macroeconomic variables, given that the Bolivian economy went through structural changes in the last two decades. In that sense, this paper uses a Bayesian time-varying parameter structural vector auto-regressive model (TVP-SVAR) with stochastic volatility. The results show that the effect of the international oil price on economic growth decreased between 2000 and 2018 due to a volume effect (lower external demand) as a value effect (low oil prices). The pass-through of international food prices to domestic inflation is significant and shows a slight decrease since 2015 due to a moderation in the growth rate of food imports. Finally, the nominal exchange rate appreciated initially to mitigate the imported inflationary pressures and, subsequently, thanks to the greater income of foreign currency to the economy, also its degree of response decreased over time due to the lower effect on economic growth and reduced external inflationary pressures.

JEL classification: *F41, C32, F31, E31.*
Keywords: *Price commodities, economic growth, inflation, time-varying parameters, TVP-SVAR.*

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1. Introduction

The effects of fluctuations in international commodity prices have been a source of debate among economists, researchers and policy makers for a long time. Globalization and growing world trade have motivated a broad literature about the impact of commodity price fluctuations on economic activity, both in developed and developing countries, applying a wide variety of instruments in order to quantify these effects. One of the main findings of the empirical evidence is that the effects of commodity prices are not complete and change over time (IMF, 2011; and Al-Shawarby and Selim, 2012). Especially, the effects of variations in oil prices and food prices have been the focus of numerous research papers.

Bolivia is a small, open and commodity exporter economy, so it has been exposed to different external shocks, mainly to fluctuations in commodity prices. This situation encouraged many researchers to know more precisely the magnitude of the effects of commodity prices. Although it was confirmed on several occasions that commodity price movements had significant effects on economic performance, it was not considered whether there were changes in the relationship between commodity prices and internal macroeconomic variables, given that the Bolivian economy went through structural changes. For example, the hydrocarbons sector acquired an important role thanks to the high export volumes of natural gas (the sale price is influenced by the international oil price). Also, there was a significant increase in imports of food and other goods, which would imply that currently imported goods have a greater participation within the household consumption structure.

For this reason, this document analyzes whether there were changes in the relationship between commodity prices and the main local macroeconomic variables in the last two decades. A Bayesian time-varying parameter structural vector auto-regressive model (TVP-SVAR) with stochastic volatility was used, following Primiceri (2005), Del Negro and Primiceri (2015), Essaadi (2016), and Kang, Ratti and Vespignani (2017). The West Texas Intermediate (WTI) oil prices and the FAO (Food and Agriculture Organization of the United Nations) Food Price Index were used as external variables, while economic growth and inflation represent internal variables. Additionally, the nominal exchange rate was introduced to reflect the response of the monetary policy. Data were used monthly, considering the period between January 1992 and December 2018 (the first 96 observations were used as training samples to calibrate the distribution of priors). All the variables were introduced in logarithms and year-to-year variations were used to avoid seasonal problems.

This document is organized in six sections. The following part describes the evolution of commodity prices and their main effects. Subsequently, the performance of the Bolivian external sector is briefly explained. Next, the methodology used is detailed. The results obtained are presented in the fifth section. Finally, the conclusions are presented.

2. Evolution of commodity prices and their effects

Globalization and growing world trade have motivated a broad literature about the impact of commodity price fluctuations on economic activity, both in developed and developing countries. Many empirical approaches have been used to quantify the impacts of these shocks on different macroeconomic variables of interest.

Especially the effects of variations in the price of oil have been the focus of many investigations (there have been studies since the 1970s). The price of this commodity is quite volatile since it is affected by several factors (Espinoza and Vaca, 2012): i) the structural demand for crude oil, correlated with the global macroeconomic dynamism; ii) the cost of production, influenced by investments in oil fields as well as the application of new technologies; iii) the time with which the production capacity is extended; iv) financial markets generate a speculative component; and v) geopolitical risks that affect production, transport and distribution.

The effects of oil price fluctuations depend on whether it is an importing or exporting country (Lescarouxy and Mignon, 2008; and Berument, Ceylan and Dogan, 2010). In the case of importing economies, an increase in the oil price leads to an increase in domestic prices and an economic slowdown (Doğrul and Soytas, 2010; and Aydin and Acar, 2011).

In the case of exporters, an increase in the oil price benefits the local economy thanks to higher foreign currency inflows. Nevertheless, it would also have adverse effects such as a rise of inflation (Rodríguez, 2011). On the contrary, a fall in oil prices can lead to a recession (Kilian, 2005). This indicates that oil price movements can cause significant macroeconomic fluctuations in these economies (Mehrara and Oskui, 2007).

From the document of Paladines and Paladines (2017), different transmission channels can be identified by which oil price fluctuations affect the local economies. The first channel that can be mentioned is the cost. A rise in the oil price implies an increase in the prices of fuels consumed by families and firms, the latter could transfer the higher costs to the prices of final goods (Tang, Wu and Zhang, 2010). The final effect would be reflected in an inflationary rebound.

The next channel is the exchange rate. Given an increase in the oil price, the local currency would be expected to appreciate as a measure to mitigate the impact of the rising price of imported fuels, even if this means a loss of competitiveness. However, the final reaction depends on the exchange rate regime; for example, Céspedes et al. (2005) indicate that a flexible exchange rate allows smoothing fluctuations caused by external shocks. On the other hand, Volkov and Yuhn (2016) point out that oil price shocks can cause volatility in the exchange rates of exporting countries.

Another channel that should be considered is the fiscal one. A rise in the oil price implies a greater income of resources for the Government of exporting countries, which causes an increase in investment and public spending (Huseynov and Ahmadov, 2013); the latter can translate into higher inflation (Farzanegan, 2011). On the contrary, a fall in the price of oil reduces fiscal revenues, affecting public expenditure and the execution of future projects.

Meanwhile, international food price movements and their consequences have similarly generated great interest among economists. The evolution of food prices is also determined by several elements, which can be divided into two groups (Piñeiro and Bianchi, 2009). The first corresponds to long-term factors: i) the greater demand from developing countries, in line with an increase in population and an improvement in income; ii) the increasing use of biofuels; iii) land productivity per hectare; and iv) regulations for the preservation of the environment. In the second group there are the short-term factors: i) the behavior of the oil price, which sends signals to the rest of the commodities and affects production and transportation costs; ii) the evolution of the US dollar and other assets in this denomination (investors seek refuge in commodities when the dollar shows weakness); iii) weather conditions; and iv) the volatility caused by the financial markets.

Most studies mainly studied the effects on domestic prices. The rise in food prices results in higher inflation, in emerging and developing economies (González and Langebaek, 2007; Al-Shawarby and Selim, 2012; and Ahsan, Iftikhar and Ali Kemal, 2012) and in advanced economies (Lee and Park, 2013). Lora, Powell and Tabella (2011) mentioned that, in the case of Latin America, the speed and magnitude of the effects depend on the flexibility of the exchange systems, the degree of importer or exporter of food and the relevance of imported food in household consumption.

Other papers focused on social aspects, especially in cases of emerging or developing countries. One of the main conclusions was that the rise in food prices has implications for poverty by restricting the access of groups with less purchasing power to these products. There are a large number of documents for Latin America that investigate this point (Ivanic and Martin, 2008; Soto and Faiguenbaum, 2008; and Piñeiro and Bianchi, 2009).

Not only the effects of commodity prices on local economies attract the attention of researchers, so did the relationship between oil prices and food prices. Esmaeili and Shokoohi (2011) found that oil prices have an indirect effect on food prices. For their part, Baumeister and Kilian (2014), pointed out that food prices react to oil price shocks, but there is no evidence that the same thing happens in the opposite direction. While Zmami and Ben-Salha (2019) found that the effects of oil prices towards food prices are asymmetric.

Certainly, a co-movement can be observed between these two variables in the last decade. Both the oil price and food prices showed a volatile evolution since the 1990s, however, it became more fluctuating from the 2000s (Figure 1). The prices of both showed substantial increases between the periods 2007–2008 and 2010–2011, caused mainly by a greater dynamism of world economic activity, especially by emerging economies, among other factors. They also exhibited pronounced falls in 2009 and 2014–2015 which were influenced mainly by a global economic slowdown, along with other elements.

Figure 1: Evolution of commodity prices

a) Levels (Price per barrel in dollars and Index 2002-2004=100) | b) Year-to-Year (Percentage)

Source: FAO – Bloomberg.

The effects of fluctuations in commodity prices are a source of debate among economists, researchers and policy makers. The documents of the IMF (2011) and Al-Shawarby and Selim (2012) indicate that among the main findings of the literature about the effects of international food prices, it was found that: i) the effect to domestic prices is not complete and changes over time; ii) are asymmetric effects (Ferrucci, Jiménez-Rodríguez and Onorante, 2010); and iii) the impact is greater in emerging and developing economies than in advanced economies. These inferences could be valid in the case of the effects of the oil price, taking into account the results of the works of Essaadi (2016) and Kang, Ratti and Vespignani (2017).

3. Bolivian external sector behavior

Bolivia was born to independence with an export heritage of commodities (especially minerals at the beginning). In that sense, it is not surprising that external conditions, mainly fluctuations in international commodity prices, have played an important role in the performance of its economic activity throughout its history.

In the 19th century, silver production was the main economic activity until the beginning of the 20th century, when changes in the global economic and monetary matrix caused a crisis of silver mining. In contrast, the new international framework increased demand for tin, which boosted the national external sector and brought deep structural changes[2]. During this period, the high income generated by the mining sector, encouraged a greater importation of luxury goods and food. Sometime later, the tin market would be affected by the outbreak of the First World War, which would have negative effects on the local economy.

Later, between the sixties and seventies, the economy was driven by activities related mainly to the local market such as commerce, while the extractive sector lost importance. The country's main exports at that time were tin (which represented almost 70%) and hydrocarbons[3], a sector that began to gain prominence thanks to the Gulf Oil Company's investment in this sector and the export of natural gas to Argentina[4].

In the first half of the eighties, Bolivia went through one of the worst economic crises in its history. The situation became more complex when international prices of minerals began to fall, especially of tin (a sharp decline in the London Metal Exchange). The good performance of hydrocarbons was also affected by delays in payments from Argentina and fluctuations in international prices. This period

[2] With the fall of silver mining, the Mint (*Casa de la Moneda*) was paralyzed, ceasing to produce the potosine currency (worldwide accepted for transactions for decades). This caused the Bolivian economy to become more sensitive to fluctuations in the prices of its exports, especially tin and rubber (BCB, 2015).

[3] In 1965, the Investment Promotion Law (*Ley de Fomento a las Inversiones*) was enacted, given advantages to foreign investment in mining and hydrocarbons.

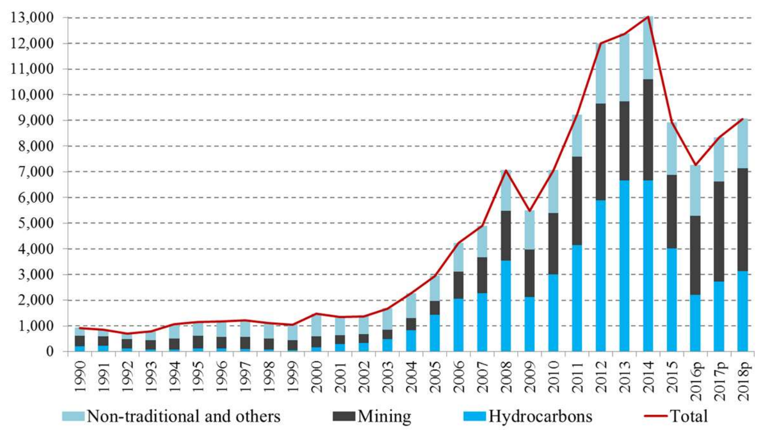
[4] In May 1972, the era of hydrocarbons begins with the signing of the long-term sales contract (1972-1992) with the Republic of Argentina.

was characterized by: i) lower foreign currency earnings and depreciation pressures[5]; ii) drop in imports[6]; and iii) reduced tax revenues due to falling taxes from exports and import tariffs[7].

In the 1990s, exports barely exceeded $1 billion (Figure 2a). The share of mineral exports decreased from 44% in 1990 to 29% in 2000, affected by the fall in the price of tin (which extended until 2002) and its repercussions on the mining sector. Meanwhile, hydrocarbons did not represent an important sector, on average they represented 10%, affected by low international oil prices and limited volumes of natural gas exports to Argentina. Given the weakness of the extractive sectors, non-traditional sectors were the main exports of the country. On the other hand, imports were slightly higher than exports, $1.5 billion on average (Figure 2b), resulting in continuous current account deficits in this period. The majority corresponded to capital and intermediate goods, while almost $330 million (23%) were consumer goods (of which about 53% were durable goods such as vehicles, furniture and electronic devices)

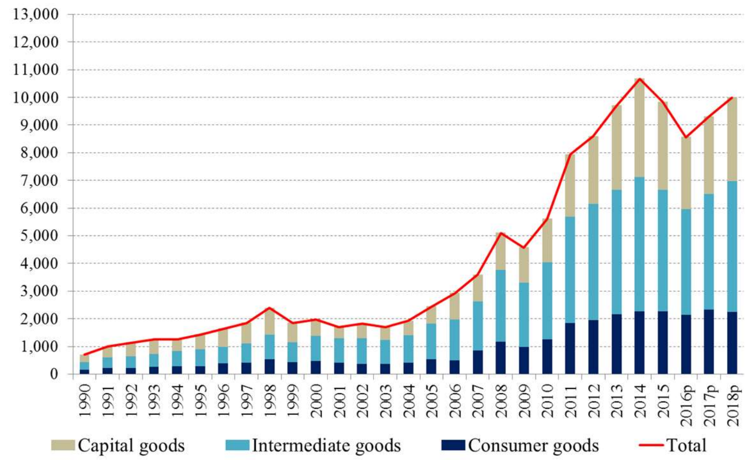
Figure 2: Development of Bolivian external sector
(In millions of US dollars)

a) Exports



[5] Kiguel and Liviatan (1988), mention that the tin crisis in October 1985 caused a massive devaluation of the local currency.
[6] According to Morales, Espejo and Sheriff (1991), public sector imports (mainly for investment) were quite sensitive to the variation in revenues from minerals and hydrocarbons.
[7] Morales, Espejo and Chávez (1992) indicated that public sector accounts were possibly the most important mechanism of transmission of export price fluctuations to the internal economy.

b) Imports



Source: National Statistics Institute - Central Bank of Bolivia.
Note: (p) preliminary data.

Between 2000 and 2003, exports on average were close to $1.5 billion, while imports were around $1.8 billion. During this time, the hydrocarbons sector acquired a greater importance thanks to the export of natural gas to Brazil, which began in July 1999[8]. On the other hand, imports fell due to lower domestic demand for the effects of the currency crises in South America on the national economy.

A favorable external context was seen between 2004 and 2014, since exports increased from $2.27 billion to $13.30 billion. Analyzing by sectors, hydrocarbon exports increased from $851 million to $6.68 billion in this period. In that sense, the outstanding increase of Bolivian exports was mainly due to the increasing export of hydrocarbons (Figure 3a) thanks to: i) the highest demand for natural gas from Brazil and Argentina, ii) high international oil prices[9], and iii) the implementation of different productive projects.

The increase in exports caused a greater income of resources to the economy, which stimulated a greater consumption of both local and external goods and services. Between 2000 and 2014, imports increased from $1.98 billion to $10.67 billion, a rise of 476% (Figure 3b). Although, capital and intermediate goods continued to represent the majority of imports (about 80%); consumer goods also showed a strong increase, from $466 million to $ 2.29 billion in the same period. Especially, a greater amount of non-durable consumer goods was imported (they accounted for about 58% of consumer

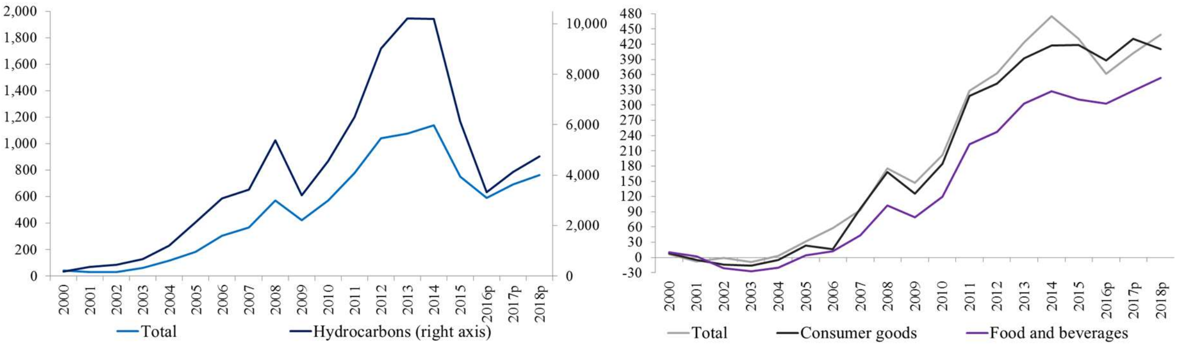
[8] The energy relationship between Bolivia and Brazil began in 1936, when the governments of both countries signed an agreement for the use and export of Bolivian oil to Brazil. In February 1993, the first contract of sale was signed between Bolivian Fiscal Oil Fields (Yacimientos Petrolíferos Fiscales Bolivianos) and Petroleos Brasileiros (Petrobras). The factor that would definitively seal the energy relationship between the two countries was the Rio Grande - San Pablo binational gas pipeline, a colossal project that began in July 1997 and was completed in February 1999 (CBHE, 2015).

[9] The oil price has an influence on the sale price of natural gas because in the sales contracts it was established that the effective price for a given quarter (Brazil) or semester (Argentina) is calculated based on the average price ratio of different types of fuel oil, which change in line with the international WTI oil price. It is for this reason that the oil price became a relevant variable for the Bolivian economy.

goods), highlighting the importation of food and beverages (from $114 million to $441 million). Therefore, imported goods acquired a greater participation in the consumption structure of families.

Figure 3: Cumulative growth compared to 1999
(In percentages)

a) Exports b) Imports



Source: National Statistics Institute - Central Bank of Bolivia.
Note: (p) preliminary data.

From the second half of 2014, the external context became adverse. Exports fell by -32% in 2015 and -19% in 2016 mainly due to a decrease in hydrocarbon exports (-40% and -44% in the same years). This sector was affected by a substantial decrease in the oil price from $100 to $50 and, additionally, a lower demand from Brazil and Argentina due to the slowdown in their economies. In the last two years, exports showed a slight improvement. The participation of hydrocarbons fell from 45% in 2015 to 35% in 2018, but it remains important for the local economy.

Imports also decreased, although in a lesser magnitude, with rates of -8% in 2015 and -13% in 2016. Analyzing by groups, imported consumer goods were the least affected, precisely between 2015 and 2018 they remained around $2.26 billion, while imported food and beverages on average were equal to $437 million, which would indicate that Bolivian families continued demanding imported products. Like exports, imports grew slightly in the last two years.

Given this reality, an extensive literature emerged in Bolivia in order to better understand how variations in international prices of commodities affect the national economy. A period that caught the attention of researchers was the economic crisis of the 1980s. Numerous documents explained what role the external sector plays in this turbulent stage. The works of Morales, Espejo and Sheriff (1991), Morales, Espejo and Chávez (1992) and Morales (1992) can be mentioned.

Between the 1990s and the first five years of the 21st century, the behavior of the external sector was affected by different shocks. In that sense, several papers concluded that the Bolivian economy was significantly vulnerable to external shocks (Nina and Brooks, 2001; Loza, 2002; and Jemio and Wiebelty, 2002). However, another group of studies focused on the potential benefits of natural gas exports (Andersen and Meza, 2001 and Andersen and Faris, 2001).

The boom in international commodity prices encouraged the emergence of a large number of investigations, most of them focus in the positive effects (economic growth, social welfare), but also in the negative aspects (inflationary rebounds) and the indirect effects (development of the financial system), with greater emphasis on the hydrocarbons sector. Documents from the IMF (2008), Lora, Powell and Tabella (2011), Trajtenberg, Valdecantos and Vega (2015), Murillo and Pantoja (2015), and Aguirre and Grillo (2017) can be reviewed.

Even though it was corroborated on different occasions that commodity price movements had significant effects on Bolivian economic activity, the possible changes that could have occurred in the relationship between commodity prices and internal macroeconomic variables were not considered, since the economy went through important structural changes.

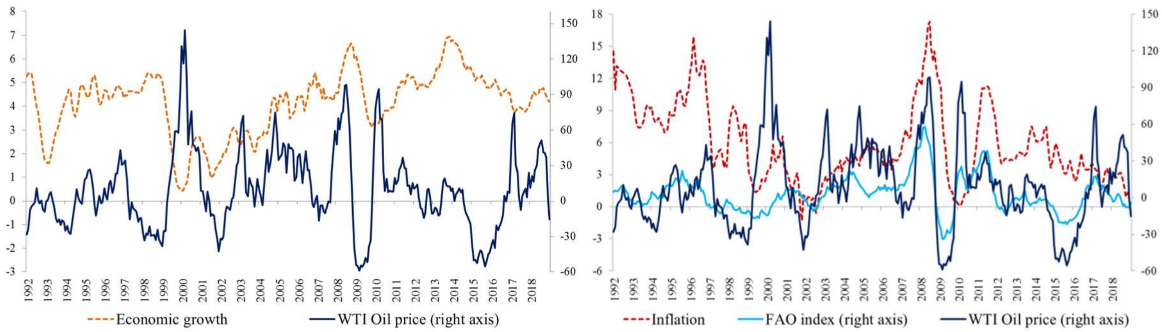
On the one hand, the hydrocarbons sector acquired a greater relevance not only in exports but also in the public sector revenues[10] and, therefore, in economic activity. A rise in the price of this energy improves the terms of trade, which favors the performance of the economy (Figure 4a). Between 2000 and 2003 the average annual economic growth rate was almost 2.5% (the oil price was for $30 per barrel), while between 2004 and 2007 the average annual growth rose to 4.5% (the oil price increased from $30 to $80). The highest growth rates were recorded between 2008 and 2014 (without considering 2009), on average it was 5.5% (the oil price reached $100). Between 2015 and 2018 the average growth rate was 4.4%, in a context of falling oil prices from $100 to $31 (February 2016) with a temporary recovery to $71 (October 2018).

On the other hand, imported goods obtained a greater participation in the consumption structure of families, so changes in international commodities prices should have greater repercussions on local prices, especially in the case of food[11], since the prices of fuels have been subsidized since the 1990s[12]. For example, between December 2006 and June 2008, year-on-year headline inflation increased from 4.9% to 17.3%, when the year-on-year variation in international food prices rose from 10.3% to 43.4% (Figure 4b). Another important rise in world food prices occurred between June 2010 and April 2011 (from 11.4% to 38.2%), coinciding with an increase in year-on-year headline inflation (from 2.2% to 11%). The rise in international prices of commodities would have generated inflationary pressures through different channels: i) rising prices of consumer goods; ii) higher cost of inputs[13]; and iii) shortage of products in local markets[14].

[10] Government hydrocarbon revenues in the early 2000s were close to $400 million, while in recent years they were around to $2 billion.
[11] Food and beverages are the group with the greatest weight in the basic basket of the Consumer Price Index (CPI) of Bolivia (42% according to the 2016 CPI base).
[12] See Medinaceli (2012) for more information.
[13] In BCB (2008) it is noted that between 2007and 2008, the rise in world grain prices led to an increase in the cost of balanced food and inputs used by meat and milk producers.
[14] High international food prices encouraged local producers to allocate a greater part of their supply to foreign markets, generating a shortage in domestic markets. Given this situation, several countries, including Bolivia, imposed restrictions on exports, price controls or both, with the purpose of supplying their internal markets and controlling prices (Braun, 2008).

Figure 4: Evolution of internal variables and commodity prices
(Year-to-Year, in percentages)

a) Economic growth b) Inflation



Source: National Statistics Institute – FAO – Bloomberg.

4. Empirical methodology

Taking into account that the effects of international commodity prices change over time (IMF, 2011; and Al-Shawarby and Selim, 2012) and that there is no study for Bolivia that considers this aspect, the objective of this document is to analyze if there is a change in the relationship between commodity prices and the main local macroeconomic variables.

A Bayesian time-varying parameter structural vector auto-regressive model (TVP-SVAR) with stochastic volatility was used, following Primiceri (2005), Del Negro and Primiceri (2015), Essaadi (2016), and Kang, Ratti and Vespignani (2017); therefore, it is a multivariate time series model with both time-varying coefficients and time-varying variance-covariance matrix.

As Primiceri (2005) pointed out, time-varying coefficients allow us to capture the existence of nonlinearities or changes in the time lag structure. Meanwhile, the time-varying variance-covariance matrix (multivariate stochastic volatility) helps to capture the existence of a possible heteroscedasticity of the shocks and nonlinearities in the simultaneous relations between the variables included in the model. In this way, the data is allowed to determine whether the time variation of the linear structure comes from changes in the size of the shocks (impulse) or from changes in the propagation mechanism (response).

4.1. The Model

Consider the next model:

$$y_t = c_t + \beta_{1,t} y_{t-1} + \cdots + \beta_{k,t} y_{t-k} + \mu_t \qquad (1)$$
$$t = 1, \ldots, T.$$

Where y_t is an $n\ x\ 1$ vector of endogenous variables which are observable; c_t is an $n\ x\ 1$ de time-varying coefficients that multiply constant terms; $\beta_{i,t},\ i = 1, \ldots, k$ are $n\ x\ n$ time-varying VAR coefficients that multiply the lags of the endogenous variables in vector $y_{t-i},\ i = 1, \ldots, k$; μ_t are heteroscedastic unobservable shocks with variance-covariance matrix Ω_t.

In order to allow the variance-covariance matrix Ω_t to change over time, consider the triangular reduction of Ω_t, such that:

$$\Omega_t = A_t^{-1}\Sigma_t\Sigma_t'\left(A_t^{-1}\right)'$$

Which is equivalent to:

$$A_t\Omega_t A_t' = \Sigma_t\Sigma_t' \qquad (2)$$

Where A_t is the lower triangular matrix:

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha_{nn-1,t} & 1 \end{bmatrix}$$

and $\sum_t$ is the diagonal matrix:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix}$$

Therefore, equation (1) can be rewritten as:

$$y_t = c_t + \beta_{1,t}y_{t-1} + \cdots + \beta_{k,t}y_{t-k} + A_t^{-1}\Sigma_t\varepsilon_t \qquad (3)$$

Where ε_t is the vector of the i.i.d. errors (independent identically distributed) and its variance is equal to an identity matrix of dimension n, $var(\varepsilon_t) = I_n$.

Equation (3) can be rewritten by stacking all the right-hand-side coefficients in a vector β_t, to obtain:

$$y_t = X_t'\beta_t + A_t^{-1}\Sigma_t\varepsilon_t \qquad (4)$$

Where:

$$X_t' = I_n \otimes \left[1, y_{t-1}', \ldots, y_{t-k}'\right]$$

Where the symbol $\otimes$ denotes the Kronecker product.

In equation (4) it should be noted that it is essential to allow the matrix A_t to vary over time, since otherwise, a shock or an innovation to the *i-th* variable would have the same effect over time on the *j-th* variable. This would be undesirable in this model, since the objective is modeling time variation in a simultaneous equation model.

The estimation strategy consists in of modeling the coefficient processes in equation (4). Next, the law of motion for the parameters of the model must be specified[15]. For this purpose, α_t is defined as the vector of non-zero and non-one elements of the matrix A_t (stacked by rows) and σ_t as the vector formed by the elements of the main diagonal of the matrix $\sum_t$. Then, the dynamics of the model's time varying parameters is specified as follows:

$$\beta_t = \beta_{t-1} + v_t \qquad (5)$$

$$\alpha_t = \alpha_{t-1} + \zeta_t \qquad (6)$$

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t \qquad (7)$$

Where β_t and α_t, which represent the coefficients of the VAR and the elements of the matrix A_t, follow a random walk process, while the standard deviations (σ_t) follows a geometric random walk, which allows to work with a stochastic volatility structure. In this way, it is ensured that the variables change permanently and you can work with a reduce number of parameters in the estimation procedure.

It can be seen that the proposed model follows the form of the state-space models where equation (4) represents the measurement equation and equations (5), (6) and (7) represent the state equations. All the innovations in the model (ε_t, v_t, ζ_t, η_t) are assumed to be jointly normally distributed with the following assumptions on the variance covariance matrix:

$$V = Var\left(\begin{bmatrix} \varepsilon_t \\ v_t \\ \zeta_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \qquad (8)$$

Where Q, S and W are defined as positive matrices. The adoption of this form for matrix V responds to two needs. First, it allows reducing the number of parameters to be estimated, a model like this already has a large number of parameters to estimate, and estimating them outside the main diagonal of matrix V would require the inclusion of a sensitive prior able to prevent cases of ill-determined parameters. Second, it allows a structural interpretation of the innovations. Finally, it is assumed that the matrix S is block diagonal, which allows the coefficients of contemporary relationships among variables to evolve independently. This assumption, although not essential, simplifies the inference and increases the efficiency of the estimation algorithm.

[15] The same assumptions of Primiceri (2005) are used.

4.2. Information and estimation strategy

This document uses monthly data for the period January 1992 to December 2018. All the variables were introduced in logarithms and year-to-year variations were calculated to avoid seasonal problems. Also, given the complexity of the model and with the purpose of preserving the degrees of freedom, the estimation of the model was carried out with two lags, although without neglecting the stability of the model.

In the case of commodity prices, the WTI oil price (whose data was obtained from Bloomberg) and the FAO Food Price Index were used. On the other hand, I employed the Global Economic Activity Index (IGAE) accumulated as a proxy variable of the economic activity in monthly frequency and the Consumer Price Index (CPI) to calculate inflation, the information of both variables come from the National Institute of Statistics.

Finally, the nominal Exchange Rate (ER) was introduced to reflect the response of the monetary policy to mitigate the effects of external shocks. Bolivia has adopted a crawling– peg exchange rate regime since 1985, so the official ER is administered by the Central Bank of Bolivia (BCB). The behavior of the ER under this regime denotes two completely different periods. The first period (1990–2005) was characterized by constant depreciation of the national currency with the objective of maintaining the external competitiveness of the economy; however, this caused a high pass-through towards domestic prices and a strong dollarization. The second period (2006–2018) was identified by appreciations and stability, since the exchange rate policy was reoriented to mitigate external inflationary pressures (caused by the rise in international commodity prices) and to maintain the confidence in the local currency facing an external scenario of uncertainty[16].

Although this variable is relevant for this model, it has a drawback. The ER has been fixed since 2011, which is not favorable when someone uses SVAR models. In that sense, and only for methodological purposes, the Weighted Average Exchange Rate (*Tipo de Cambio Promedio Ponderado, TCPP*)[17] will be used as a proxy variable. The TCPP reflects the same behavior as the official ER although with slight variations in recent years (Figure 5).

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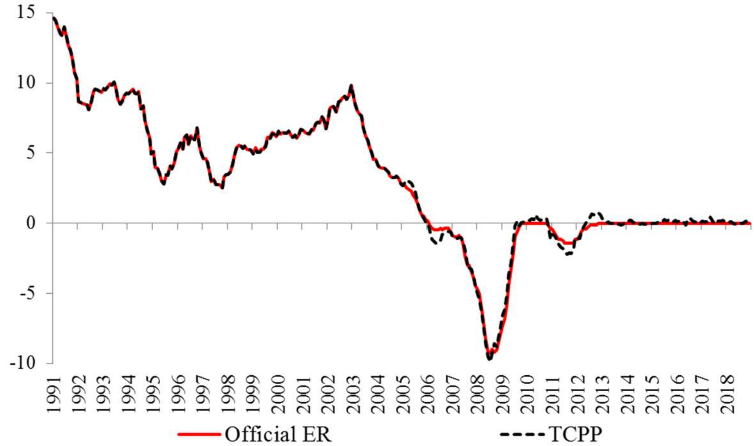
[16] For more information, it is recommended to see Chapter 2: The Exchange Policy of the book "*Soberanía Monetaria, Estabilidad Macroeconómica y Desarrollo Económico y Social Volumen II*", BCB (2018).

[17] The TCPP is a variable calculated by the BCB that reflects the weighted average value of the sale and purchase exchange rate of standard (carried out through the windows and ATMs) and preferential (carried out at preferential prices with clients that have negotiation capacity) operations between the financial system and its customers.

Figure 5: Behavior of the official exchange rate and the TCPP (Year-to-Year, in percentages)



Source: Central Bank of Bolivia.

4.3. Identification and structural interpretation

Starting from equation (4) and considering that

$$\Xi_t = A_t^{-1}\Sigma_t$$

Is obtained:

$$y_t = X_t'\beta_t + \Xi_t \varepsilon_t$$

It is in the matrix Ξ_t ($t = 1,\ldots, T$) where the $\frac{n*(n-2)}{n}$ necessary restrictions that guarantee identification for any period t are introduced. It is worth mentioning that n represents the number of variables in the model.

According with Kang, Ratti and Vespignani (2017), the Cholesky decomposition is used to orthogonalize the residuals (lower triangular matrix) and it is assumed that TCPP responds instantly to all structural shocks in the system. Growth and inflation respond immediately to commodity prices structural shocks, but respond to TCPP shocks later.

4.4. Bayesian inference

Since I will work with unobservable variables, the most optimal way to make estimates is to use Bayesian methods. Therefore, first, the priors for the different parameters must be defined; those priors will define the starting points and distributions of the estimates to be made. Later, Bayesian methods are used to evaluate the distribution of the posteriors of the parameters of interest, which are the unobservable variables (β^T, A^T, $\sum^T$) and the hyperparameters of the variance-covariance matrix V. For the numerical analysis of the posteriors of the parameters of interest the Gibbs Sampler algorithm is used.

Following Primiceri (2005), it is assumed that the initial state values for the coefficients, for the covariances, for the variances in logarithms and the hyperparameters are independent of each other. In the case of the priors of the hyperparameters, Q, W and the S blocks, are assumed to be distributed as independent inverse-Wishart. The priors for the initial states of the time-varying coefficients, the simultaneous relations and the log standard errors, $p(\beta_0),\ p(\alpha_0)$ and $p(log\ \sigma_0)$, are assumed to be normally distributed. These assumptions, together with the law motion equations (5), (6) and (7), imply normal priors on the entire sequences of $\beta, \alpha\ and\ log\ \sigma$, conditional on Q, S and W.

The first eight years of the sample (96 observations, from 1992:M1 to 1999:M12) were used to calibrate the distribution of the priors, this training sample is represented by τ. For the mean and variance of $\beta_0\ and\ A_0$, the Ordinary Least Squares (OLS) point estimates were chosen and four times the estimated variance with a normal VAR with the training sample. In the case of $log\ \sigma_0$, the mean of the distribution is the logarithm of the OLS point estimates of the standard errors of the same normal VAR model, while the variance-covariance matrix is arbitrarily assumed to be the identity matrix.

$$\begin{aligned}
&\mathrm{B}_0 \sim N(\hat{\mathrm{B}}_{OLS}, 4 \bullet V(\hat{\mathrm{B}}_{OLS})), \\
&A_0 \sim N(\hat{A}_{OLS}, 4 \bullet V(\hat{A}_{OLS})), \\
&\log \sigma_0 \sim N(\log \hat{\sigma}_{OLS}, I_n),
\end{aligned}$$

As Primiceri (2005), for the matrix Q the degrees of freedom are equal to τ, S_l denotes the corresponding blocks of the matrix S, while $\hat{A}_{l,OLS}$ represents the corresponding blocks of $\hat{A}_{OLS}$. With these considerations, the following distributions were used for the scale matrices:

$$\begin{aligned}
&Q \sim IW(k_Q^2 \bullet V(\hat{B}_{OLS}), \tau), \\
&W \sim IW(k_W^2 \bullet (1+\dim(W)) \bullet I_n, (1+\dim(W))), \\
&S_l \sim IW(k_S^2 \bullet (1+\dim(S_l)) \bullet V(\hat{A}_{l,OLS}), (1+\dim(S_l))),
\end{aligned}$$

The following values were taken into account for the parameters: $k_Q = k_W = 0.01$ and $k_S = 0.1$. The results of the estimate were obtained from 40,000 iterations with the Gibbs sampler algorithm, in line with Primiceri (2005) and Del Negro and Primiceri (2015), discarding the first 20,000 for convergence[18]. To avoid possible autocorrelation of the draws, only every 10th iteration was kept.

5. Results

This section contains the results of the impulse-response functions of internal variables to international commodities prices shocks.

[18] The Appendix 8.1 contains the diagnosis of the convergence of hyperparameters.

5.1. Responses to Oil Price Shocks

The estimated median responses to an unexpected increase in the international oil price are consistent with the results of other documents; there is an increase in international food prices, greater economic growth and an appreciation of the national currency, but in the case of inflation, results are not exactly as indicated in the literature (Figure 6).

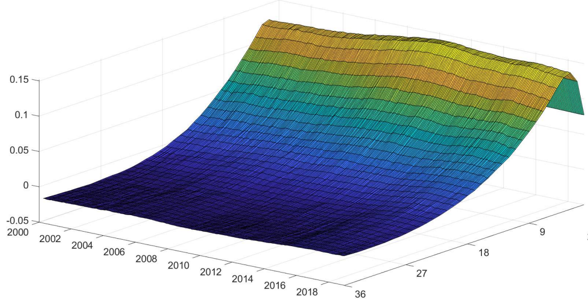
There are no significant effects immediately on economic growth; it is after 6 months that positive effects begin to be observed. This shock is quite persistent since after 24 months its effect tends to disappear. A rise in the oil price does not mean that Bolivia will receive higher revenues immediately because the prices established in gas sales contracts to Brazil and Argentina consider the average oil price of the last quarter and semester, respectively. However, this mechanism is what causes this shock to be persistent. Over time, higher revenues eventually lead to greater public and private consumption, which produces an output increases.

The nominal exchange rate appreciates immediately and this response increase as more foreign currency inflow to the local economy. The highest appreciation is observed after 12 months, and this is maintained for a long period, up to 24 months. As in the previous case, this result is explained by gas sales contracts, which generate a lagged and persistent effect of oil price shocks.

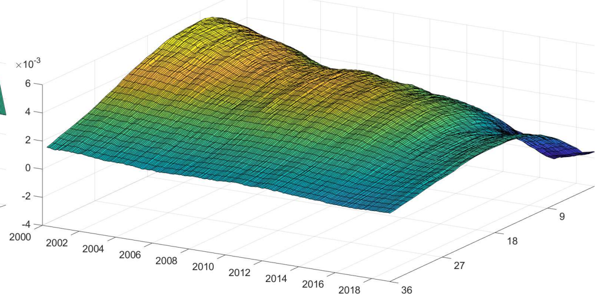
In the case of inflation, an oil price shock has a negative effect in the first months (contrary to what the literature exposes), after 12 months a positive response is observed. The fuel prices in Bolivia are subsidized; therefore, they do not follow the dynamics of international prices. A rise in the oil price does not immediately generate higher revenues, but yes higher expenses. The Government must spend a greater part of its resources to pay for more expensive imported fuels, which means that spending in other sectors must be reduced or postponed, this implies a lower income of resources to the local economy and, then, lower inflationary pressures. Later, as resources increase for both the public and private sectors, there is greater domestic consumption and, therefore, an increase in inflation.

Figure 6: Time-Varying Impulse Responses to a 1% Oil Price Shock

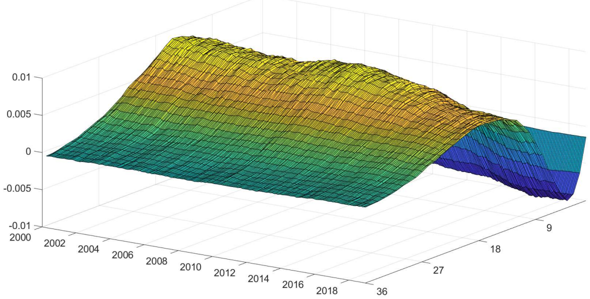
a) International food prices



b) Economic growth



c) Inflation



d) Exchange rate

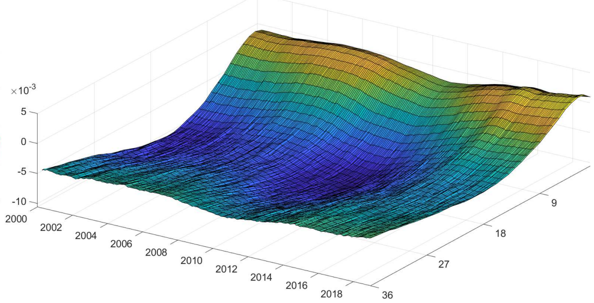
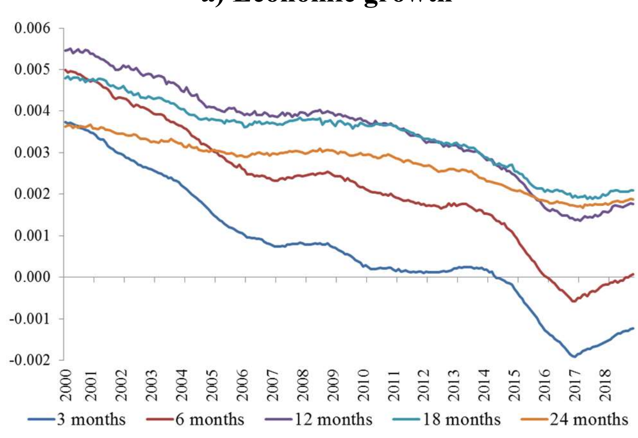


Figure 7 shows more clearly the time-varying responses of internal variables to oil price shocks. In 2000, an oil price shock had a faster and stronger effect on economic growth. Since then, the degree of response decreased, initially gradually, stabilizing between 2005 and 2013 and in a more accelerated way in the recent years. The most notable changes occurred in the 3 and 6 month horizons that became negative.

This result is in line with the behavior of hydrocarbon exports (Figure 8). These registered their highest annual growth in 2000 for two reasons: i) a greater volume of gas sales to Brazil thanks to the start-up of the Rio Grande - San Pablo gas pipeline and ii) a substantial growth in the oil price[19]. Since then, although the hydrocarbons sector showed significant growth rates, they were not of the same magnitude, neither the oil price grow at that rates again[20]. After 2014, the value of hydrocarbon exports decreased (with negative variations between 2015 and 2016) due to the economic slowdown in Brazil and Argentina, which caused them to demand lower volumes of Bolivian gas, as well as the sharp fall in the oil price (from about $100 to $50 in six months). These factors would explain why the economic growth response to oil price shocks fell more in recent years[21].

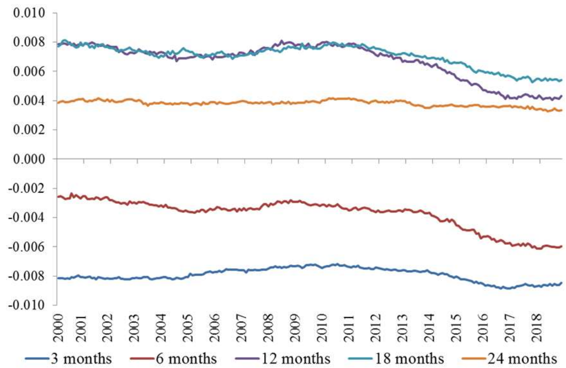
Figure 7: Responses to Oil Price Shock at selected horizons over different periods

a) Economic growth



[19] Between December 1999 and March 2000 the oil price registered year-to-year variations equal on average to 123%, see Figure 1b.
[20] The highest year-to-year rates were 98% in mid-2008 and 90% in the first quarter of 2010.
[21] In section 5.3 there is a complementary analysis on this point.

b) Inflation



c) Exchange rate

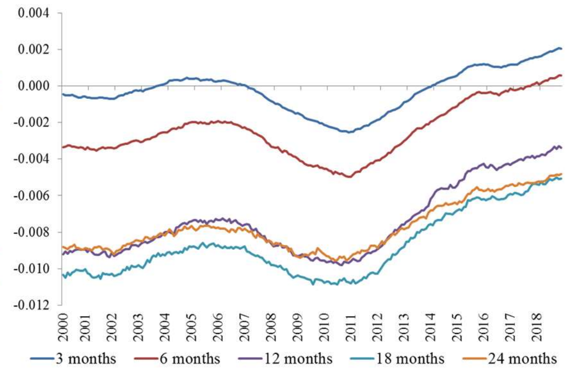
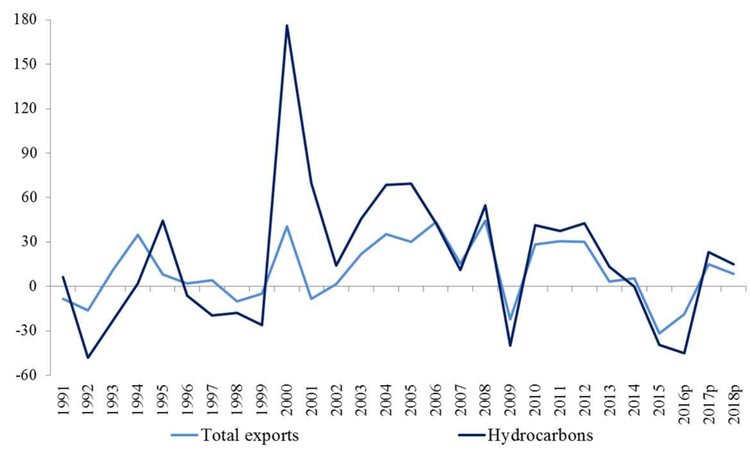


Figure 8: Annual growth of Bolivia's exports
(In percentages)



Source: National Statistics Institute - Central Bank of Bolivia.
Note: (p) preliminary data.

The response of inflation did not reflect relevant changes over time (Figure 7). The most striking change is observed in the 12-month horizon, which reflects a lower degree of response since 2014. While, the degree of exchange rate response also declined over time. The greatest appreciations are observed between the horizons of 12 to 24 months, especially between 2007 and 2011. However, since 2013, a lower degree of response is observed, even in the 3 and 6 month horizons, depreciations are seen, which are explained by the negative effects on economic growth in these horizons. In that sense, the exchange rate does not respond in the same magnitude as before due to the decrease in the degree of economic growth response.

5.2. Responses to Food Price Shocks

An unexpected increase in food prices (Figure 9) has a positive effect on economic growth (improvement of export prices of food products[22], the greatest impact is after 9 months), higher inflation (with immediate effects) and an appreciation of the national currency (monetary policy

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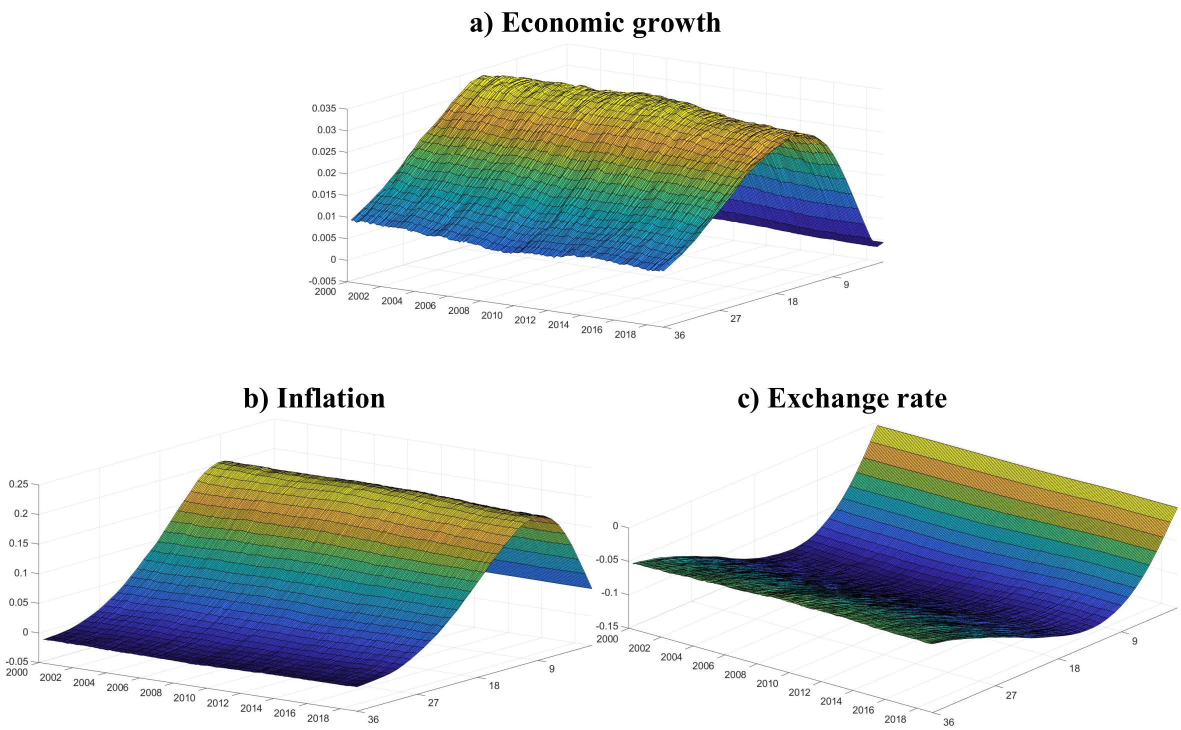
[22] Bolivia's main exports include soybean and soybean meal and the FAO index considers the changes in international prices of vegetable oils.

response instantly to mitigate the effects of higher imported inflation). However, there are no changes in the degree of response over time of the variables despite the fact that food prices showed a volatile pattern as in the case of oil prices and that the import of food products showed significant growth in the last two decades.

Figure 9: Time-Varying Impulse Responses to a 1% Food Price Shock



5.3. Complementary analysis

From these results, a second model was estimated with the same specifications but only including the oil price. Possibly, part of the effects of oil price fluctuations are transmitted through variations in international food prices, this would be the reason why the responses of internal variables to food price shocks did not change over time, since those changes in time would already be captured with oil price shocks. It should be taken into account both variables reflected a similar evolution, denoting a co-movement in recent years. Precisely, carrying out a cross-correlation analysis between the year-to-year variations of the oil price and food price considering the 2007-2018 period, it is found that this is quite high (0.77). Also, several studies show that oil price has significant repercussions on food prices (Piñeiro and Bianchi, 2009; Esmaeili and Shokoohi, 2011; Baumeister and Kilian, 2014; and Zmami and Ben-Salha, 2019).

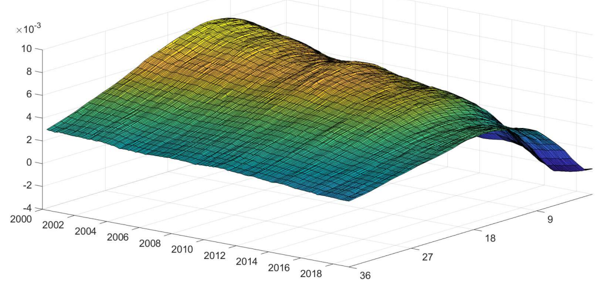
The estimated median responses to an unexpected increase in the international oil price (Figure 10) with Model 2 are similar to those of Model 1 in section 5.1. An increase in the economic growth is observed except that the degree of response is of greater magnitude for the different horizons (confirming that food prices shock reflected part of the of the oil price shock). The strongest responses are observed between the horizons of 12 and 18 months.

Inflation reflects an increase almost immediately unlike Model 1 because oil price shocks are now transmitted through international food prices in the short term, which have repercussions on domestic food prices. Although, the degree of response in Model 2 is of greater magnitude, it does not have the same degree of persistence. For example, in Model 1 the greatest impact was seen between the horizons of 12 and 18 months, while with Model 2 the greatest impact is on the horizon of 12 months and since then it tends to fall. This would be explained by the appreciation of the national currency that mitigates external inflationary pressures.

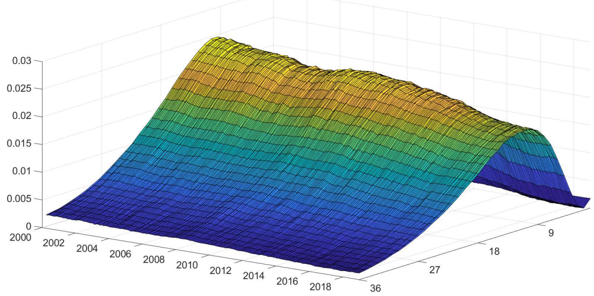
The response of the nominal exchange rate shows an appreciation of greater magnitude and in less time with respect to the results of Model 1. This is explained by two reasons: i) initially, as response of the monetary policy to mitigate the inflationary pressures imported; and ii) later, thanks to the increased of foreign currency inflows. Therefore, the highest appreciation rates are observed between the horizons of 12 months to 18 months.

Figure 10: Time-Varying Impulse Responses to a 1% Oil Price Shock with Model 2

a) Economic growth



b) Inflation



c) Exchange rate

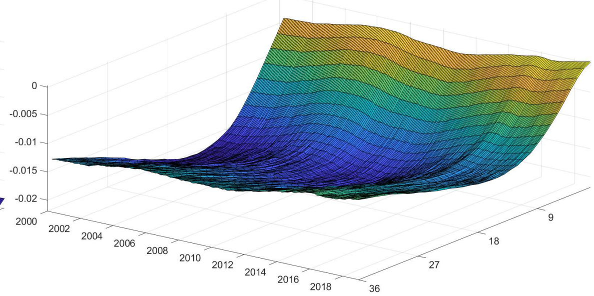


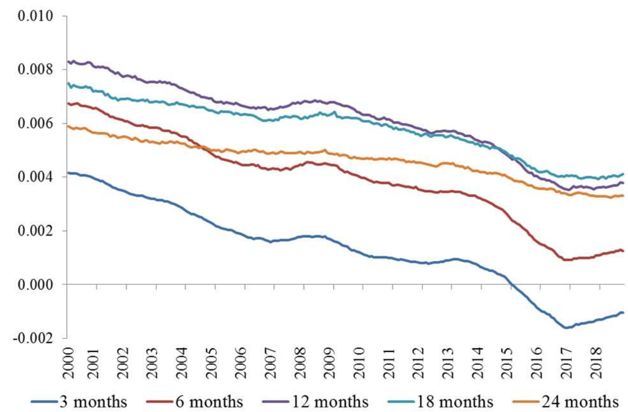
Figure 11 shows the evolution over time of the changes in the responses of the internal variables to the shocks of the oil price in Model 2. In the case of economic growth, its response to different horizons reflects the same downward trajectory than in Model 1 (the explanation for this is found in section 5.1), although it is of greater magnitude. It is worth mentioning that the response in the 6 month horizon does not become negative as in the results of Model 1.

The headline inflation response shows a slight decrease in the last four years. In the early 2000s, inflation was affected by the effect of oil price on the economic activity (foreign income stimulated greater private and public consumption generating inflationary pressures). Between 2006 and 2014, inflation was mainly affected by fluctuations in international food prices, during this period there was an increase in food imports. Since 2015, the degree of response has fallen slightly because the growth rate of food imports was moderated and to the low levels of international commodity prices.

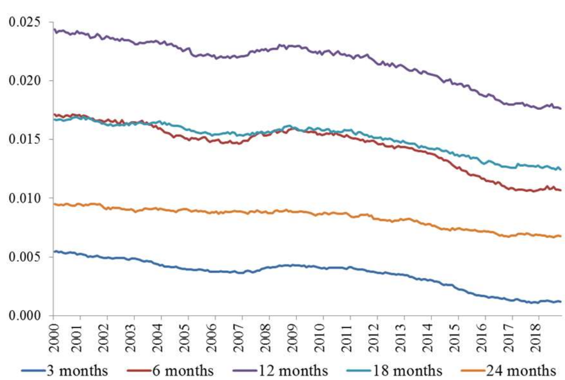
The exchange rate reflects an appreciation of greater magnitude than in section 5.1, and depreciations are no longer observed in the 3 and 6 month horizons. Likewise, there is a decrease in the degree of response over time due to the lower effect of the oil price on the economic growth (lower foreign currency inflows); and the weakness of the international commodity prices (lower external inflationary pressures).

Figure 11: Responses to Oil Price Shock at selected horizons over different periods with Model 2

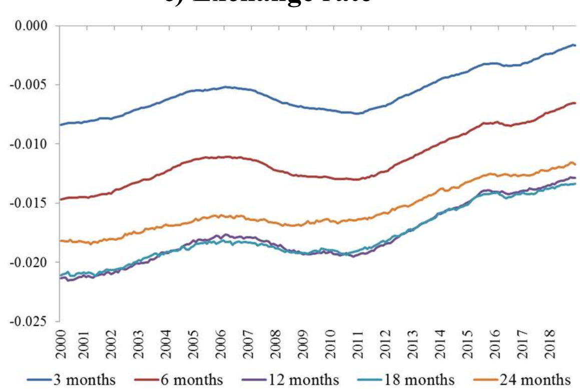
a) Economic growth



b) Inflation



c) Exchange rate



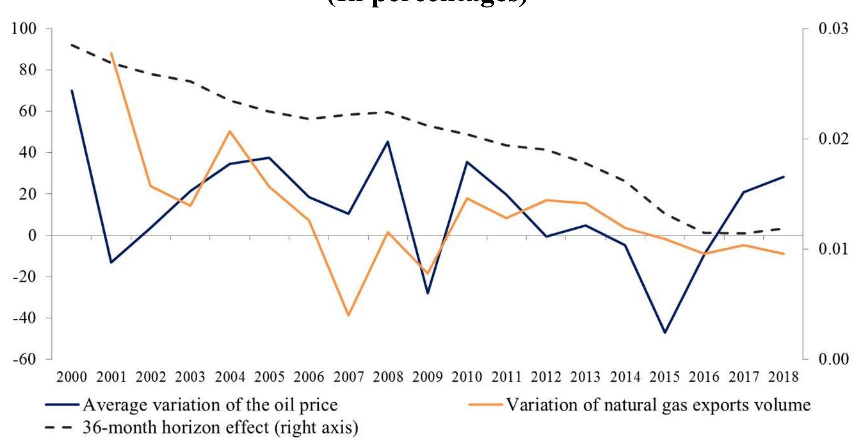
The transfer coefficients were calculated from the results of Model 2 (Table 1). For this purpose, the results of the accumulated impulse-response functions were used to assess the impact of commodity prices over the Bolivian economy over time.

Table 1: Effect of a 1% increase in the oil price with Model 2
(In percentages)

	Economic growth				Inflation					Exchange rate				
	12 months	18 months	24 months	36months	6 months	12 months	18 months	24 months	36 months	6 months	12 months	18 months	24 months	36 months
2000	0.01	0.01	0.02	0.03	0.01	0.02	0.04	0.05	0.06	-0.01	-0.02	-0.04	-0.05	-0.08
2001	0.01	0.01	0.02	0.03	0.01	0.02	0.04	0.05	0.06	-0.01	-0.02	-0.04	-0.05	-0.08
2002	0.01	0.01	0.02	0.03	0.01	0.02	0.04	0.05	0.06	-0.01	-0.02	-0.03	-0.05	-0.08
2003	0.01	0.01	0.02	0.03	0.01	0.02	0.04	0.05	0.06	-0.01	-0.02	-0.03	-0.05	-0.07
2004	0.01	0.01	0.02	0.02	0.01	0.02	0.04	0.04	0.06	-0.01	-0.02	-0.03	-0.04	-0.07
2005	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.04	-0.07
2006	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.04	-0.07
2007	0.01	0.01	0.02	0.02	0.01	0.02	0.04	0.04	0.05	-0.01	-0.02	-0.03	-0.05	-0.07
2008	0.01	0.01	0.02	0.02	0.01	0.02	0.04	0.05	0.06	-0.01	-0.02	-0.03	-0.05	-0.07
2009	0.01	0.01	0.01	0.02	0.01	0.02	0.04	0.04	0.05	-0.01	-0.02	-0.03	-0.05	-0.07
2010	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.05	-0.07
2011	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.05	-0.07
2012	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.04	-0.06
2013	0.005	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.02	-0.03	-0.04	-0.06
2014	0.004	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.05	-0.01	-0.01	-0.03	-0.04	-0.06
2015	0.002	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.04	-0.005	-0.01	-0.02	-0.03	-0.05
2016	0.001	0.004	0.01	0.01	0.005	0.02	0.03	0.03	0.04	-0.005	-0.01	-0.02	-0.03	-0.05
2017	0.002	0.004	0.01	0.01	0.005	0.02	0.03	0.03	0.04	-0.004	-0.01	-0.02	-0.03	-0.05
2018	0.002	0.005	0.01	0.01	0.005	0.02	0.03	0.03	0.04	-0.003	-0.01	-0.02	-0.03	-0.05

In the case of economic growth, the results reflect that an increase of 1% in the oil price would not have significant effects in the first months, produces a year-to-year growth of 0.01% after 12 months (between 2000 and 2012) and of 0.02% after 24 months (between 2000 and 2008), while in a 36-month horizon the effect fell from 0.03% (2000-2003) to 0.01% (2015-2018). This drop is explained by both a value and volume effect. Between 2000 and 2003 the annual variations in the oil price and the volume of natural gas exports were quite high, while since 2015 there was a fall in the volumes of natural gas exports accompanied by low oil prices (Figure 12). These results are similar to those presented in the document of the IMF (2014). According to their results, based on a Global VAR (GVAR) model, in the case of Bolivia, a 10% increase in export commodity prices causes an annual growth of almost 0.3% after three years. In this case, a 10% growth in the price of oil produces a year-to-year economic growth of 0.3% after 36 months, but this would only have occurred between 2000 and 2003.

Figure 12: Annual variation in the oil price and the volume of sales of natural gas, with the transfer coefficient for the 36-month horizon
(In percentages)



Source: National Statistics Institute – Bloomberg.

An increase of 1% in the oil price (which would be channeled initially through international food prices) generates an average increase of year-to-year inflation of 0.01% in the first 6 months, of 0.02% in 12 months and of 0.03% in 18 months. In the horizons of 24 and 36 months the effects fell from 0.05% to 0.03% and from 0.06% to 0.04%, respectively. These results would indicate that the effects on inflation would have remained basically stable in the first 18 months, after this horizon the effects would have decreased, in line with the lower effect on economic growth.

To be more precise with the quantification of the impact of international food prices on domestic inflation, the pass-through coefficients were calculated using the results of Model 1 (Table 2). An increase of 1% in international food prices (FAO index) generates an average year-to-year increase of 0.09% at 6 months, of 0.15% at 12 months, of 0.20% between 18 and 24 months, and of 0.30% at 36 months. In the horizon of 36 months, the effect fell slightly in the last years because food imports were moderated (on average its annual growth rate was 1.6% between 2015 and 2018), although, it remained at high levels (near $400 million). These final values are similar to the results obtained by Lora, Powell and Tabella (2011), who, with a VAR model, found that headline inflation in Bolivia increases by 0.12% and 0.17% after 6 months and 18 months, respectively, after a 1% rise in world food prices.

Table 2: Effect of a 1% increase in international food prices over inflation Model 1 (In percentages)

	3 months	6 months	12 months	18 months	24 months	36 months
2000	0.06	0.09	0.15	0.20	0.24	0.29
2001	0.05	0.09	0.15	0.20	0.24	0.29
2002	0.05	0.09	0.15	0.20	0.24	0.29
2003	0.05	0.09	0.15	0.20	0.24	0.29
2004	0.05	0.09	0.15	0.20	0.24	0.29
2005	0.05	0.09	0.15	0.20	0.24	0.29
2006	0.05	0.09	0.15	0.20	0.24	0.29
2007	0.05	0.09	0.15	0.20	0.24	0.29
2008	0.05	0.09	0.15	0.20	0.24	0.29
2009	0.05	0.09	0.14	0.20	0.24	0.29
2010	0.05	0.09	0.14	0.20	0.24	0.29
2011	0.05	0.09	0.14	0.19	0.23	0.28
2012	0.05	0.09	0.14	0.19	0.23	0.28
2013	0.05	0.09	0.14	0.19	0.23	0.28
2014	0.05	0.09	0.14	0.19	0.23	0.27
2015	0.05	0.09	0.14	0.19	0.23	0.27
2016	0.05	0.09	0.14	0.19	0.23	0.27
2017	0.05	0.09	0.14	0.19	0.23	0.27
2018	0.05	0.09	0.14	0.19	0.23	0.27

The exchange rate responds to a shock of the oil price slightly after 6 months and the degree of response increases over time. An increase of 1% in the oil price produces a year-to-year appreciation of -0.01% at 6 months (between 2000 and 2014), of -0.02% at 12 months (between 2000 and 2013), the effect drops from -0.04% to -0.02% at 18 months, from -0.05% to -0.03% at 24 months and from -0.08% to -0.05% at 36 months. The exchange rate response decreased due to the lower effect of the oil price on economic growth and the weakness of the international commodity prices (lower external inflationary pressures).

6. Conclusions

The objective of this document is to analyze if there is a change in the relationship between commodity prices and the main local macroeconomic variables, given that the Bolivian economy went through structural changes in the last two decades. On the one hand, the hydrocarbons sector acquired an important role thanks to the high export of natural gas (whose sale price is influenced by oil price movements). On the other hand, there was a significant increase in food imports, which would imply that there is currently a greater participation of imported goods in the family consumption structure. Using a Bayesian TVP-SVAR model with stochastic volatility, it was found that fluctuations in commodity prices did have an effect on Bolivian economic activity but these would have diminished over time.

In the case of economic growth, using the results of Model 2, it was found that an increase of 1% in the oil price produces a year-to-year growth of 0.01% after 12 months (between 2000 and 2012) and of 0.02% after 24 months (between 2000 and 2008), while in a 36-month horizon the effect fell from 0.03% (2000-2003) to 0.01% (2015-2018). This lower response is in line with the behavior of hydrocarbon exports. These recorded their highest annual growth rates between 2000 and 2003, both because to a value effect (a substantial rise in the oil price) and volume effect (higher levels of natural gas exports to Brazil). Subsequently, although the hydrocarbons sector continued to show significant growth rates, they were not of the same magnitude. Since 2015, there has been a more pronounced decrease in the transfer effect in line with the fell in the volume of exports of natural gas (lower demand from Brazil and Argentina due to the deceleration of their economies) accompanied by low oil prices (affected by lower growth of the world economy).

An increase of 1% in the price of oil (which would be channeled initially through international food prices) generates an average increase of year-to-year headline inflation of 0.01% in the first 6 months, of 0.02% in 12 months and of 0.03% in 18 months. In the horizons of 24 and 36 months the effects fell from 0.05% to 0.03% and from 0.06% to 0.04%, respectively. The effects on inflation remained basically stable in the first 18 months, after that horizon the effects would have decreased due to the lower effect on economic growth (lower resources from abroad, lower consumption increase, lower inflationary pressures).

To complement the results and have a more precise quantification of the impact of international food prices on domestic inflation, the transfer effect was calculated using the results of Model 1. An increase of 1% in international food prices generates a year-to-year increase of 0.09% on average at 6 months, of 0.15% at 12 months, of 0.2% between 18 and 24 months, and of 0.3% at 36 months. Since 2015, in the horizon of 36 months, the effect fell slightly in the last years because food imports were moderated (although, it remains at high levels) and low international commodity prices.

In the case of the nominal exchange rate, an increase of 1% in the oil price produces a year-to-year appreciation of -0.01% at 6 months (between 2000 and 2014), of -0.02% at 12 months (between 2000 and 2013), the effect falls from -0.04% to -0.02% at 18 months, from -0.05% to -0.03% at 24 months and from -0.08% to -0.05% at 36 months. Initially, the national currency appreciated as a response of monetary policy to mitigate imported inflationary pressures; and, later thanks to the increased of foreign currency inflows. Likewise, there is a decrease in the degree of response over time due to the lower effect of the oil price on economic growth (lower foreign exchange inflows); and the weakness of the international commodity prices (lower external inflationary pressures).

In summary, an increase in international commodity prices would not favor economic growth as at the beginning of the 21st century; however, it would have a significant effect on domestic inflation. It is recommended to continue evaluating how the effects of the external context changed but considering other sectors to better understand by which channels the national economy may be more affected today.

7. Bibliografía

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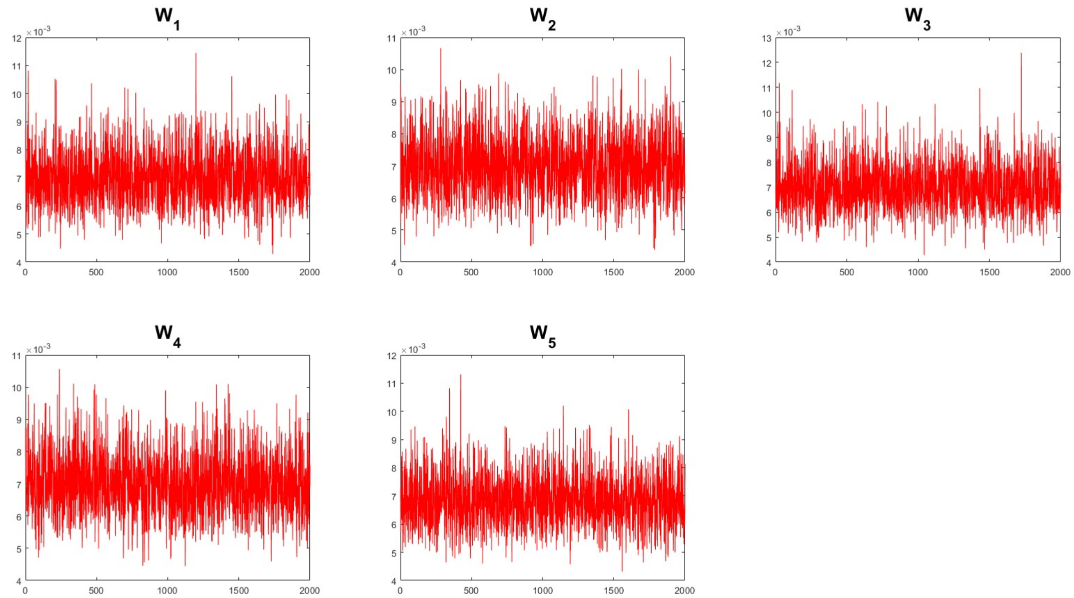
8. Appendix

8.1. Diagnosis of convergence of hyperparameters Model 1



8.2. Diagnosis of convergence of hyperparameters Model 2