PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

ESCUELA DE POSGRADO

Natural resources, corruption, human development, economic growth, prices of minerals and fiscal fluctuations

TESIS PARA OPTAR EL GRADO DE DOCTOR EN ECONOMÍA

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Junio, 2021

Abstract

This thesis analyzes issues related to natural resources, corruption, human development, economic growth, prices of minerals and fiscal fluctuations. It is composed of two studies. The first one analyzes the effects of corruption on economic growth, human development and natural resources in Latin American and Nordic countries using a Bayesian panel VAR model. The results reveal some relevant contrasts between both groups of countries: (i) in Latin America there is support for the sand the wheels hypothesis in Bolivia and Chile, support for the grease the wheels hypothesis in Colombia and no significant impact of corruption on growth in Brazil and Peru. By contrast, the response of growth to shocks in corruption is significantly negative in most of periods in all Nordic countries; (ii) corruption negatively affects human development in all countries from both regions; (iii) corruption tends to spur natural resources sector in Latin American countries, especially in Brazil, Colombia and Peru. By contrast, corruption is detrimental for the activity of natural resources sector in all Nordic countries. Furthermore, results for the full sample, Latin American and Nordic countries are obtained from two alternative approaches, namely, a Panel Error Correction VAR model and an Asymmetric Panel VAR model. The second study analyzes the evolution of the effects of fluctuations in mineral commodity prices on fiscal variables, especially those associated with fiscal revenues, in Peru by means of VAR models with time-varying parameters and stochastic volatility (TVP-VAR-SV). Different alternative specifications are compared using the marginal likelihood and the deviance information criterion. It is found that an increase of 1% in the growth of mineral commodity prices generates increases of around 1.5% and 2.5% in the growth of taxes from mining and mining canon, respectively, thus reflecting a remarkable sensitivity of these variables to external shocks. In turn, these responses are increasingly more pronounced until reaching a peak around 2009 and then decrease, which is in line with the dynamics of the commodities boom. In the variance decomposition, the importance of shocks in mineral commodity prices in explaining fluctuations in taxes from mining and mining canon increases in line with the increasing tendency of mineral prices until the Great Recession, where shocks in mineral commodity prices explain between 40% and 50% of fluctuations in taxes from mining and mining canon, and then it is reduced. This shows the importance of allowing time-varying parameters and stochastic volatility in contrast with a standard VAR.

Acknowledgments

I am very thankful to my advisor Gabriel Rodríguez for his encouragement, patience, advice and support during all this process. He has greatly inspired me to be a better researcher and professor. I would also like to thank Alejandro Lugón (Doctoral Program Director), José Távara, Patricia Tovar, Jorge Rojas and Waldo Mendoza for their useful comments that allow me to substantially improve the papers which correspond to this thesis. I also want to thank my parents, Dante Javier and Rosa Angélica, for their support during this academic challenge. To my wife, Andrea Castro, thank you so much for your unconditional love and support, especially during the most difficult parts of this adventure. Finally, I want to thank God, who works in all things for the good of those He loves. After this doctorate, I become not only a better researcher but also a better person.

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INTRODUCTION

A relevant issue in development economics is that there are many countries that are rich in natural resources but, at the same time, are far from having achieved sustainable economic growth and development. Authors like Acemoglu and Robinson (2012) associate this failure to the existence of "extractive institutions", which are linked to corruption since in resource-rich countries corrupt elites organize rent-seeking structures to enrich themselves. Other authors associate this problem with macroeconomic instability since changes in commodity prices can affect resource-rich economies by generating fluctuations in fiscal variables or other macroeconomic aggregates. In this context, the present thesis analyzes issues related to natural resources, corruption, human development, economic growth, prices of minerals and fiscal fluctuations by applying macroeconometric methods. It is composed of two studies.

The first one analyzes the effects of corruption on economic growth, human development and natural resources. The study of the effects of corruption has become a very important topic in economics research. This is mainly due to the increasing international concern on the problem of corruption around the world. The most notorious examples of this are the World Bank Anticorruption Strategy, the United Nations Anticorruption Treaty, the OECD Convention on Bribery of Foreign Public Officials in International Business, and the Extractive Industries Transparency Initiative. In fact, the World Bank has categorized corruption as "the single greatest obstacle to economic and social development".

The study compares the effects of corruption in Latin American and Nordic countries. In fact, this is the first study on economics of corruption which directly compares those regions. In the case of Latin America, it suffers from widespread corruption, as exemplified by the Odebrecht scandal, which is one of the biggest corporate corruption cases in history. At the same time, Latin American economies have benefitted greatly from the commodities boom by means of the increase in their natural resources exports. Besides, in the case of Nordic countries, it is well known that they have high levels of transparency and institutional quality. Given this, they have made good use of their natural resources and have reached a sustainable economic growth and a very high level of human development. Consequently, compare regions with these differences can give us interesting patterns about the effects of corruption.

The econometric analysis is based on the estimation of a Bayesian panel VAR model with a hierarchical prior. The impulse response functions (IRFs), the forecast error variance decomposition (FEVD), and the historical decomposition (HD) are obtained for each country. Robustness tests are applied by considering alternative hyperparameters, priors and ordering of the variables. In addition, two alternative approaches are considered, namely, a Panel Error Correction VAR model and an Asymmetric Panel VAR model.

So, this first study contributes to the literature by presenting evidence about the relationships among corruption, natural resources, human development and growth for Latin American and Nordic countries. In turn, it presents a methodological improvement by using a Bayesian panel VAR model to deal with the endogeneity problem which, as seen, is still an issue in several previous studies. In fact, this is the first time that this method is applied in the literature on economics of corruption and it has the advantage of allowing us to have specific results for each country, which is important to examine issues in which there can be mixed evidence.

The second study analyzes the evolution of the effects of fluctuations in mineral commodity prices on fiscal variables, especially those associated with fiscal revenues, in Peru. The debate on the consequences of resource dependency has been closely linked to the so-called "natural resources curse," a concept coined by Auty (1993) in his study about the development of mineral economies. From this perspective, it is maintained that the abundance of resources, instead of being a blessing, would be a curse for countries because it would lead to problems such as macroeconomic instability. In this way, economies that rely heavily on exports of primary commodities are particularly exposed to the uncertainty associated with commodity price movements. This clearly affects fiscal variables. When commodity prices are rising, as in the commodities boom, tax revenues have substantial increases and this can lead to overspending, which aggravates fiscal procyclicality. In turn, when commodity prices are decreasing, as during the Great Recession or at the end of the commodities super cycle, government revenues and expenditures also tend to decrease. This problem is particularly relevant for mineral-dependent economies since many mineral commodities fluctuate remarkably in the short term.

In this context, it is important to study the case of Peru since it is an economy in which the mining sector is clearly relevant. Mining accounts for nearly 60% of Peruvian total exports; see Ernst & Young Peru (2019). In fact, Peru is a significant global mining player since it is among the largest producers of copper, silver and zinc around the world. In turn, it is the largest exporter of copper to China, which is the world's largest consumer of this metal. Besides, Peru scores 80.1 out of 100 in the Mining Contribution Index, which measures the relative importance of mining to the economy of a country, so that it is qualified as resource-dependent.

The econometric analysis is based on a time-varying parameters vector autoregression with stochastic volatility (TVP-VAR-SV). Given this, different restricted models can be specified depending on which parameters we want to keep constant, namely: (i) TVP-VAR-SV which considers both time-varying parameters and stochastic volatility; (ii) TVP-VAR which assumes homoscedastic variances; (iii) TVP-VAR-R1-SV which assumes that intercepts and coefficients of lagged variables are constant; (iv) TVP-VAR-R2-SV which assumes that the coefficients of the contemporaneous effects are constant; (v) TVP-VAR-R3-SV which assumes that only the intercepts and the variance are time-varying; (vi) CVAR-SV which assumes constant parameters and stochastic volatility; and (vii) CVAR which assumes constant parameters and constant volatility. Following Chan and Eisenstat (2018), the model comparison is performed by using the calculation of marginal likelihood and the deviance information criterion. The impulse response functions (IRFs), the forecast error variance decomposition (FEVD), and the historical decomposition (HD) are obtained for each model.

So, this second study contributes to the literature by presenting evidence about the evolution of the effects of mineral commodity prices on fiscal fluctuations in Peru. The analysis is performed by estimating a vector autoregression model that allows for time variation both in the VAR coefficients and the entire variance matrix of the shocks (TVP-VAR-SV); see Primiceri (2005). This represents an important methodological improvement regarding the previous literature which uses a VAR approach with constant parameters and constant volatility; see, for example, Kumah and Matovu (2007), Raddatz (2007), De Gregorio and Labbé (2011), Medina (2016).

The remainder of this thesis is structures as follows. The first chapter presents the paper analyzing the effects of corruption on economic growth, human development and natural resources in Latin American and Nordic countries. The second chapter presents the paper analyzing the evolution of the effects of fluctuations in mineral commodity prices on fiscal variables in Peru. Lastly, it is included a section with the main conclusions of both studies.

CHAPTER 1: The Effects of Corruption on Growth, Human Development and Natural Resources: Empirical Evidence from a Bayesian Panel VAR for Latin American and Nordic countries

ABSTRACT. This paper analyzes the effects of corruption on economic growth, human development and natural resources in Latin American and Nordic countries using a Bayesian panel VAR model. The results reveal some relevant contrasts between both groups of countries: (i) in Latin America there is support for the sand the wheels hypothesis in Bolivia and Chile, support for the grease the wheels hypothesis in Colombia and no significant impact of corruption on growth in Brazil and Peru. By contrast, the response of growth to shocks in corruption is significantly negative in most of periods in all Nordic countries; (ii) corruption negatively affects human development in all countries from both regions; (iii) corruption tends to spur natural resources sector in Latin American countries, especially in Brazil, Colombia and Peru, which suggests that corruption could be "facilitating" extractive operations in these countries. By contrast, corruption is detrimental for the activity of natural resources sector in all Nordic countries. Furthermore, results for the full sample, Latin American and Nordic countries are obtained from two alternative approaches, namely, a Panel Error Correction VAR model and an Asymmetric Panel VAR model.

1.1. Introduction

Corruption, defined as the abuse of public power for private benefit, is a major issue that has created international concern and a considerable amount of research has been carried out in order to better understand its economic effects. In specific, the debate has focused on whether it hampers or promotes economic activity, but empirical evidence for this relationship seems to be mixed. For instance, Li and Wu (2010) note that, while it is clear that there is a negative association between corruption and the level of income per capita across countries, the relationship between corruption and the rate of economic growth is not so clear. In this way, although there are many examples of highly corrupt countries with low economic growth and countries with low corruption that have enjoyed high growth, there are also cases of countries -like China and Indonesia- that have achieved rapid growth in a context of widespread corruption; see Wedeman (2002). Such observations suggest that the relationship between corruption and economic performance is more complex than one is commonly led to believe since there can be different trajectories across countries.

On the other hand, a relevant issue in development economics is that there are many countries that are rich in natural resources but are far from achieving economic development. Acemoglu and Robinson (2012) have pointed out that the main factor in determining if nations prosper or fail is whether they have "inclusive" or "extractive" institutions, and it is well known that corruption is closely associated with extractive institutions since in resource-rich countries with this kind of institutions, corrupt elites organize rent-seeking structures to enrich themselves.

Given this, the present study contributes to the literature by presenting evidence on the effects of corruption on growth, human development and natural resources sector in Latin American and Nordic countries. This is the first research specifically focused on the relationships among these variables and also the first study on economics of corruption which directly compares Latin American and Nordic countries. In this respect, it is important to note that there are relevant differences between both regions since Latin American countries tend to suffer from widespread corruption, while the Nordic ones have a high level of transparency.

The remainder of this paper is organized as follows: Section 2 reviews the literature on the relationship among corruption, growth, human development and natural resources sector. Section 3 explains the estimation methodology. Section 4 presents the data and the empirical results with the respective interpretation and discussions. Section 5 develops some extensions of the model by considering long run relationships and asymmetric effects. Section 6 concludes.

1.2. Literature Review

Given the purpose of this article, four relationships are relevant for the literature review: (i) corruption and growth, (ii) corruption and human development, (iii) corruption and natural resources, and (iv) corruption, growth, human development and natural resources.

1.2.1. Corruption and Growth

Regarding this relationship, there are two competing hypotheses: (i) "sand the wheels" and (ii) "grease the wheels." The argument of the first hypothesis is that corruption affects economic growth by reducing efficiency in the allocation of resources affecting the structure of incentives of the economic agents; see Olson et al. (2000). In this vein, it is argued that corruption deters growth by lowering investment, adding uncertainty on returns, given that agreements based on corruption are unenforceable. On the other hand, the second hypothesis suggests that corruption spurs growth by promoting efficiency in conditions of overregulation allowing private agents to avoid government restrictions; see Huntington (1968). Thus, corruption could compensate for the consequences of inefficient institutions and public administration by facilitating agreements, contracts, and licenses; see Méon and Weill (2010).

Empirical evidence regarding both hypotheses is mixed. In support of the first hypothesis, Mauro (1995), by using the Transparency International's Corruption Perceptions Index, finds that corruption reduces growth by lowering the level of investment. He identifies this effect by applying two-stage least squares (2SLS) considering the index of ethnolinguistic fractionalization as instrument. However, as Easterly and Levine (1997) have shown, this variable is directly correlated with growth. Besides, Gyimah-Brempong (2002) shows that the effect of corruption on growth is negative and relatively large in African countries. Likewise, Evrensel (2010), applying OLS estimation, finds that corruption is associated with lower growth rates and higher growth volatility across countries. Nevertheless, this result can be affected by endogeneity. In turn, Abu et al. (2015) find that corruption has a negative impact on GDP per capita in West African countries. In addition, considering a panel of 106 countries, d'Agostino et al. (2016) show that the negative effect of corruption on growth is exacerbated because corruption reduces government investment spending, which is growth enhancing, and increases military spending, which is growth deterring. Besides, Cieślik and Goczek (2018) find that the lack of corruption has a positive effect on the growth rate of real per capita GDP and increase investment. Similarly, Obamuyi and Olayiwola (2019) find that corruption adversely affects growth in India and Nigeria.

In support of the second hypothesis, Rock and Bonnett (2004) find that corruption increases growth in the East Asian countries. However, given that they apply OLS regressions, their results can suffer from endogeneity problem. In turn, Dreher and Gassebner (2013) show that corruption facilitates the entry of more companies into the market in the presence of excessive bureaucratic barriers, so that it can be inferred that corruption could have a beneficial effect on the economic dynamic. Huang (2016), studying thirteen Asia-Pacific countries, finds that there is a significantly positive causality running from corruption to growth in South Korea, a significantly positive causality running from growth to corruption in China and no significant causality between corruption and growth for the remaining eleven countries.

There are also studies that show mixed evidence regarding both hypotheses. Aidt et al. (2008), by using instrumental variables, find that the effect of corruption on growth is conditional on institutional quality, so that in countries with high quality institutions, corruption has a substantial negative impact on growth, and in countries with low quality institutions, corruption has no impact on growth. In a similar vein, Swaleheen (2011) shows that corruption is not growth deterring at all levels since it has negative effects on growth in countries with low levels of corruption but, above a certain threshold, it is actually growth augmenting, particularly in countries with high levels of corruption. In addition, Shabbir (2017) finds that corruption reduces growth in countries with good democratic institutions and increases growth in countries with poor democratic institutions, so that the sand the wheels hypothesis holds in Bangladesh, Indonesia, Malaysia, and Turkey, and the grease the wheels hypothesis holds in Egypt, Iran, Nigeria and Pakistan.

1.2.2. Corruption and Human Development

Corruption would be detrimental for human development. Thus, corruption can indirectly affect human development by reducing economic growth. In turn, by introducing distortions in the structure of incentives and the allocation of resources, corruption may reduce the quantity and quality of public spending destined to areas directly related to human development. In this way, Mauro (1998) points out that public officials may reduce government spending in health and education because that kind of spending offer less opportunities for rent seeking. Gupta et al. (2001) argue that corruption affects healthcare and education by increasing the cost of these services and by reducing the quality of their provision. Similarly, Gupta et al. (2002) find that corruption lowers the level of social spending, reduces schooling and increases poverty and income inequality. Akhter (2004), using the human development index in a cross-section of 75 countries, finds that corruption has a negative effect on human development. Besides, Akçay (2006) studies the relationship between corruption and human development in a sample of 63 countries and finds that there is a significantly negative relationship between these variables. Ortega et al. (2016) use panel data for analyzing how corruption affects the convergence in human development across countries and find that corruption damages growth in human development mainly through its negative impact on growth in income and health achievements. In turn, Saeed et al. (2018) point out that high levels of corruption are associated with low levels of human development. Murshed and Mredula (2018), using panel data from 2000 to 2015, find that corruption have a negative impact on human development in Asian, African and Latin American subpanels. Furthermore, Rothstein and Holmberg (2019) show that control of corruption is associated with higher levels of human development.

1.2.3. Corruption and Natural Resources

Natural resources sector is particularly susceptible to corruption. According to OECD (2016), extractive industries are the most affected by corruption since one case of transnational corruption out of five occurs in this sector. This is because natural resources generate large royalties and windfalls, so that economic agents may have incentives to organize rent-seeking structures in order to appropriate that wealth. In this context, Marshall (2001) explains that, since extractive companies operate with high sunk costs, exploration processes that delay, pressure from investors, etc., and, at the same time, require operating licenses and are subject to several regulations, they will have strong incentives to make illicit payments "to get things done." O'Higgins (2006) argues that corruption can thrive in natural resources sector because the large sums of money involved generate a confluence of interests between the supply and demand sides of corrupt exchanges. However, it must also be mentioned that corruption could dissuade some investors from initiating new projects in the natural resources sector. Buckley (2008) explains that the bargaining position of companies in the natural resources sector is weakened once their investments have been made in a specific location, so that corrupt officials could take advantage of this situation to extract more bribes and this would dissuade investments in the natural resources sector.

Moreover, Leite and Weidmann (1999), using data from natural resources exports across countries and applying 2SLS regressions, find a direct association between natural resource abundance and corruption. Gylfasson (2000) finds that heavy dependence on natural resources and agriculture may result in rent seeking. Standing (2007) shows that extractive companies in Africa press for concessions in previously protected areas, bribe local officials and fund political parties. Eigen (2007) shows that the extractive industries are particularly affected by corruption and highlights the importance of promoting policies and compromises like those of the Extractive Industries Transparency Initiative. In turn, Kolstad and Wiig (2013), using data from 81 countries and fixed-effects estimation, find that more corruption generates more extractive industry investment, although they point out that endogeneity can be still an issue in their model. Studying the case of China, Zhan (2017) argues that, since licensing processes related to health, safety and environmental protection in the natural resources sector could take several months, the heavy costs motivate companies to bribe the officials in order to speed up these processes. On the other hand, Knutsen et al. (2017) find that companies, ceteris paribus, prefer opening mines in less corrupt areas. Besides, Ogwang et al. (2019) show that there are extensive rent-seeking practices in emerging oil economies.

1.2.4. Corruption, Growth, Human Development and Natural Resources

As seen, there has been considerable discussion about different aspects of the relationship among corruption, growth, human development and natural resources. However, at present there is no empirical research directly focused on all these variables. In this context, the present paper contributes to the literature by presenting evidence about the relationships among corruption, natural resources, human development and growth for Latin American and Nordic countries. In turn, it presents a methodological improvement by using a Bayesian panel VAR model to deal with the endogeneity problem which, as seen, is still an issue in several previous studies. In fact, this is the first time that this method is applied in the literature on economics of corruption and it has the advantage of allowing us to have specific results for each country, which is important to examine issues in which there can be mixed evidence.

1.3. Methodology

We estimate a Bayesian panel VAR of the form:

$$Y_{it} = Y_{i,t-1}B_{1i} + Y_{i,t-2}B_{2i} + \cdots + Y_{i,t-p}B_{pi} + \mu_i + \varepsilon_{it}$$

where $i = 1, \ldots, N$ denotes countries, $t = 1, \ldots, T$ denotes time periods, μ_i represents dependent variable-specific panel fixed effects, p is the lag order, ε_{it} represents the idiosyncratic errors, and $Y_{it} = [y_{1it}, y_{2it}, y_{3it}, y_{4it}, y_{5it}]'$ represents the set of endogenous variables ordered as follows: export prices index, corruption index, natural resources, human development index, and domestic output. It must be noted that y_{1t} is added in order to account for the influence of the external sector into the system and all variables enter in annual growth rates.

The Bayesian panel VAR is estimated using the hierarchical prior of Gelman *et al.* (2003) which makes the model richer by treating the common mean and covariance of the VAR coefficients as random variables with a prior distribution applying to them. Following Dieppe *et al.* (2018), the estimation is performed in Matlab by means of the *Bayesian Estimation, Analysis and Regression (BEAR) toolbox*. Regarding the hyperparameters, they correspond to overall tightness (λ_1), cross-variable weighting (λ_2), lag decay (λ_3) and variance parameter (λ_4). Considering λ_1 as a random variable, we use the values suggested by Dieppe *et al.* (2018), that is, $\lambda_2 = 0.5$, which implies that own lags have more weight than lags of other variables, $\lambda_3 = 1$, which implies that the coefficient is linear, and $\lambda_4 = 100$, which implies heteroscedasticity.

In turn, the vector of coefficients is $\beta_i \sim N(b, \Sigma_b)$, such that b corresponds to a diffuse prior $\pi(b) \propto 1$, and Σ_b is designed to replicate the VAR coefficient covariance matrix Ω_b of the Minnesota prior (see Litterman, 1986). In this way: $\Sigma_b = (\lambda_1 \otimes I_q)\Omega_b$, where: $\Omega_b = \left(\frac{1}{p^{\lambda_3}}\right)^2$ if $i = j$, and $\Omega_b = \frac{\sigma_i^2}{\sigma_j^2}\left(\frac{\lambda_2}{p^{\lambda_3}}\right)^2$ if $i \neq j$. So, if Ω_b is considered as fixed but λ_1 is treated as a random variable, the determination of the full prior for Σ_b is reduced to the determination of the prior for the parameter λ_1, which is assumed that follows an Inverse Gamma distribution with shape $s_0/2$ and scale $v_0/2$, i.e. $\lambda_1 \sim IG(s_0/2\,, v_0/2)$. Then, the prior distribution is: $p(\lambda_1 |\, s_0/2\,, v_0/2) \propto \lambda_1^{-\frac{s_0}{2}-1} exp\left(-\frac{v_0}{2\lambda_1}\right)$. Here we consider a weakly informative prior by establishing low values for s_0 and v_0, so that $s_0 = v_0 = 0.001$. Then the posterior distribution is simulated using a Gibbs sampling routine and the details about the algorithm can be found in Dieppe *et al.* (2018).

We use a structural identification by triangular factorization, which assumes contemporaneous restrictions and imposes a unit contemporaneous response of variables to their own shocks. Given this, 11,000 random draws are generated and the first 1,000 draws are discarded to avoid dependence on the initial conditions. Then, a thinning of 10 is applied and with the remaining draws we compute the median and credibility intervals for the impulse-response functions (IRFs). In addition, the forecast error variance decomposition (FEVDs) and the historical decomposition (HDs) are also calculated.

1.4. Empirical Results

1.4.1. Data

This study uses panel data to investigate the relationship among corruption, growth, human development and natural resources in Latin American and Nordic countries during the period 1998-2017. In order to perform the comparative analysis, it is considered a sample of five Latin American countries with a relevant participation of natural resources exports, i.e., Bolivia, Brazil, Chile, Colombia and Peru, and the five Nordic countries, i.e., Denmark, Finland, Iceland, Norway and Sweden. Bolivia and Chile are the Latin American countries with the highest share of natural resources exports in total merchandise exports, having an average share of 88% and 84% during the study period, respectively, while, in the case of Nordic countries, Iceland and Norway have 84% and 76%, respectively. The countries with the lowest share of natural resources exports are Finland and Sweden, with 19% and 17%, respectively.

Economic growth and natural resources exports are measured by the growth rates of real GDP per capita and the sums of exports of ores and metals, fuels, agricultural raw materials and food products, respectively. This data comes from the World Bank's Development Indicators. Human development is measured by the variation of the Human Development Index from the United Nations Development Program's database. In turn, it is considered the variations of the Commodity Export Price Index from the International Monetary Fund database. As regards corruption, it is used the Transparency International's Corruption

Perception Index (CPI), which is a composite indicator based on expert's assessment of corruption levels across countries considering data sources with cross-country comparability and multi-year availability. In the CPI greater values represent higher levels of transparency. In order to have more direct interpretations with greater values linked to higher levels of corruption, in this research the index values are reversed so that 0 stands for no corruption and 100 total corruption[1].

1.4.2. Baseline Model

The baseline model corresponds to the Bayesian estimation of the panel VAR according to the specifications detailed in Section 3. Following the model selection criteria proposed by Andrews and Lu (2001), the optimal lag length for the system is p=1 since it corresponds to the lower values of the information criteria based on Akaike (1969), Schwarz (1978) and Hannan and Quinn (1979).

Impulse Response Functions (IRFs)

The dynamic effects of corruption are analyzed by means of the IRFs. In accordance with the literature review, the issues to examine are: i) how corruption affects economic growth, ii) how corruption affects human development, and iii) how corruption affects natural resources exports. The results are presented in Figures 1 to 3 considering a horizon of ten years. For ease of comparison, the IRFs are grouped per region, with Latin American countries on the left side and Nordic countries on the right side.

Regarding (i), Figure 1 shows a remarkable difference between Latin American and Nordic countries. In Latin America there is mixed evidence regarding the impact of corruption on economic growth. There is evidence for the sand the wheels hypothesis in Chile, which is precisely the country with the best institutional quality in the region having a score of 0.82 out of 1 in the Institutional Quality Index (see Krauze, 2017). In the case of the negative impact of corruption on growth in Bolivia, the result is in line with the findings of Kaufmann et al. (2002) who argue that in this country, instead of facilitating procedures, more bribery

[1] Some authors have questioned the usage of corruption indexes. However, there are also several good defenses of the validity and usefulness of the CPI. See, e.g. Lambsdorff (2004), Ko and Samajdar (2010), Heckelman and Powell (2010) and Hamilton and Hammer (2018).

results in more time wasted with bureaucracy since public officials increase formalities in order to collect more bribes. In fact, this seems to be the case because Bolivia stands at 177 in the raking of 190 economies on the ease of starting a business (see World Bank, 2017). In the case of Colombia, there is evidence for the grease the wheels hypothesis since the response of growth to shocks in corruption is significantly positive in the first period. This is consistent with the First National Survey about Practices Against Bribe in Colombian Firms, which revealed that 91 percent of the interviewees consider that there are entrepreneurs who offer bribes in their business relationships with the public and the private sector (see Corporación Transparencia por Colombia, 2008). So, in this country corruption can coexist with a dynamic business activity. In turn, corruption has no significant impact on growth in the case of Brazil and Peru. This can be due to the fact that corruption can be more institutionalized in these countries, so that shocks in corruption would not imply major alterations in the normal functioning of economic activities. This aspect can be evidenced, for example, by citizen corruption permissiveness. In this respect, Pozsgai (2015) has found that Peruvian citizens tend to have a "medium tolerance" to everyday acts of corruption like paying bribes to avoid a fine or "speed up" administrative procedures. On the other hand, in Nordic countries the impact of corruption is negative and statistically significant in most of periods in all cases. This is clear evidence in favor of the sand the wheels hypothesis and can be explained by the fact that this group of countries are the most transparent in the world and constitute the region with the highest institutional quality having an average score of 0.93 out of 1 in the Institutional Quality Index (see Krauze, 2017). In this context, shocks in corruption does imply a substantial and negative alteration in the way in which Nordic economies normally operate, so that departures from transparency remarkably affect important aspects of investment like confidence, which is detrimental for economic growth. In this way, this result is in line with the findings of Aidt et al. (2008) in the sense that corruption would have a substantial negative impact on growth precisely in countries with high institutional quality.

With respect to (ii), Figure 2 shows that the impact of corruption in human development is negative in all countries from both regions, which is in line with the findings of Akhter (2004), Akçay (2006), Ortega et al. (2016), Saeed et al. (2018), and Rothstein and Holmberg (2019). Thus, despite corruption can have a non-significant or even positive impact on economic growth in some contexts, it is in any case harmful for human development since the misallocation of resources generated by corruption involves serious distortions in key aspects for promoting human development like public investments in healthcare and education. In this way, it is observed that shocks in corruption have a negative impact on human development even in Colombia, where the effect of corruption on growth is positive, and in Brazil and Peru, where the effect of corruption on growth is not significant. Besides, this negative response is in line with that of growth in Bolivia and Chile, where there is evidence for the sand the wheels hypothesis. This result can be expected since human development can affect economic growth because as people become healthier and better educated their productive capacity will be enhanced; see Ranis et al. (2000) and Zhang and Danish (2019). Consequently, reductions in human development will negatively affect economic growth. In the case of Nordic countries, it is found that shocks in corruption have also a negative impact in human development, especially in Finland and Norway. This result can be expected since corruption involves a deterioration in institutional quality and human development is strongly associated with this variable, as shown by Balcerzak and Pietrzak (2017) for the case of developed countries. Thus, by affecting the institutional framework of the Nordic welfare state, shocks in corruption reduce human development. This negative impact of corruption in human development is in line with the responses of economic growth to shocks in corruption in all Nordic countries since there is evidence for the sand the wheels hypothesis in all of them.

As regards (iii), Figure 3 shows a remarkable contrast between countries from both regions. Regarding Latin America, corruption has a significantly positive and clearly persistent impact on natural resources exports in Brazil, Colombia and Peru. This result can be explained by the fact that extractive activities (especially those related to mining, oil, and natural gas) involve high sunk costs and exploration processes that delay at the same time that require operating licenses and are subject to several regulations, so that companies that operate in this sector have strong incentives to make illicit payments "to get things done." In this vein, it must be noted that the response of natural resources exports to shocks in corruption is in line with that of growth in Colombia since the effect is positive in both cases. With respect to Brazil and Peru, the response of natural resources exports to shocks in corruption is significantly positive while that of economic growth to shocks in corruption is insignificant, suggesting that the natural resources sector is particularly susceptible to corruption in these countries. In the case of Bolivia, the impact of corruption on natural resources exports is initially negative, which is in line with the response of growth to shocks in corruption in this country, and becomes positive from the second period. Similarly, in Chile the impact is not significant in the first period but it becomes positive from the second one. On the other hand, the impact of corruption on natural resources exports is negative and statistically significant in most of periods in all Nordic countries (albeit in Iceland, which is the least transparent Nordic country, the impact is positive in the first period but it becomes significantly negative from the second period). This result is in line with the responses of growth to shocks in corruption and suggest that, unlike Latin America, corruption is not used to facilitate extractive operations in Nordic countries. On the contrary, it seems that more corruption would dissuade investors from initiating new projects in the natural resources sector. This can be due to the fact that agents see the good institutional conditions of these countries precisely as a key advantage of investing in the natural resources sector of them. In fact, Nordic countries are well aware that they depend to a great extent on transparency in order to build credibility and create business value in the natural resources sector; see, for example, Olsson et al. (2019). Consequently, if corruption increases, this would affect this perceived advantage, thus reducing the dynamic of this sector.

Forecast Error Variance Decomposition (FEVD)

Regarding the FEVD of economic growth, Figure 4 shows that growth is noticeably influenced by the external sector given the relevance of the export price index in explaining fluctuations of growth in countries from both regions. This result can be expected since all these countries are open economies with a considerable degree of integration in international markets through trade. Corruption is not particularly relevant in explaining fluctuations of growth in Brazil and Peru. In the case of Chile and Colombia shocks in corruption account for 12.2% and 9% of fluctuations of growth in the tenth period, respectively. In turn, in Bolivia there is a substantial role of corruption since shocks in corruption account for 42.7% of fluctuations in growth in the tenth period. This can be explained by the fact that in this country increases in corruption tend to deter the economic dynamic since they are related to more restrictions and bureaucratic formalities; see Kaufmann et al. (2002), World Bank (2017). On the other hand, corruption has a relevant and increasing role in explaining fluctuations in growth in all Nordic countries, especially in Norway. This implies that shocks in corruption can represent an important source of uncertainty for economic growth in Nordic countries in the long run, which is consistent with the idea that, given that these countries have a high institutional quality, increases in corruption represent a substantial alteration which is remarkably harmful for these economies. This is reflected by the fact that Nordic citizens react more to corruption cases, generating political instability that is harmful for economic growth; see, for instance Kimpimäki (2018). In turn, shocks in natural resources exports and human development have some relevance in explaining fluctuations of growth in all countries from both regions.

With respect to the FEVD of human development, Figure 5 shows that it is mainly explained by its own shocks in all cases. External factors are less important in explaining fluctuations in the human development index than in explaining fluctuations in economic growth since human development depends more on other conditions, like those related to institutional aspects. It is noted that in countries like Brazil and Peru where shocks in corruption have a minor role in explaining fluctuations of growth, they have a more noticeable importance in explaining human development since shocks in corruption account for 10.5% and 12% of fluctuations in the human development index in the tenth period, respectively. This implies that in these countries increases in corruption can affect human development in aspects other than those directly related to per capita income. On the other hand, in all Nordic countries the importance of corruption in explaining fluctuations of human development is less than the importance of corruption in explaining fluctuations of economic growth. This can be due to the fact that the level of human development is well-established in Nordic countries since they have historically consolidated institutional conditions for ensuring their welfare states which guarantee the provision of good quality services in areas like healthcare, education and social security; see Iqbal and Todi (2015). In this way, although shocks in corruption does represent a substantial source of uncertainty for economic growth in Nordic countries, they do not represent a remarkable source of uncertainty regarding human development since the Nordic welfare states have shown resilience and persistence under different economic conditions; see Anxo (2014).

In the case of the FEVD of natural resources exports, Figure 6 shows that they are strongly influenced by the external sector since shocks in the export price index have a noticeable importance in explaining fluctuations of natural resources exports in all Latin American and Nordic countries. This result can be expected since the main source of uncertainty about the dynamic of exports lies in the evolution of international prices. Shocks in corruption has some influence in explaining natural resources exports in Latin American countries, especially in Bolivia and Brazil. In turn, corruption has also a perceptible influence in explaining natural resources exports in Nordic countries. This influence is clearly more noticeable in Iceland, where shocks in corruption account for 22.6% of fluctuations of natural resources exports in the tenth period. This can be explained by the fact that Iceland is the Nordic country with the highest share of natural resources exports in total merchandise exports and the extractive sector is particularly susceptible to corruption.

Historical Decomposition (HD)

Figure 7 shows that the export price index has played a perceptible role in explaining the dynamic of growth in all Latin American and Nordic countries, which shows that economic growth is strongly influenced by external factors. A perceptible influence of shocks in natural resource exports in explaining the dynamic of growth is also found in all countries. In turn, in the case of Latin America, shocks in corruption have a remarkable importance in explaining growth in Bolivia, especially during the period 2001-2006, in which there were corruption issues in oil contracts, and the period 2012-2017, in which there have been several corruption issues related to public procurement and road construction. There is also a noticeable importance of corruption in the dynamic of growth in Chile and Colombia. In the case of Peru and Brazil the importance of shocks in corruption is minor. However, this result must not be interpreted as implying that there is no corruption in those countries. On the contrary, it is possible that the effects of corruption are not noticeable precisely because in these countries corruption can be more institutionalized, so that it is already considered as part of the normal functioning of the economy and, consequently, shocks in corruption does not represent a substantial alteration in the dynamic of growth. It is also noted that in 1999 and 2009 there were contractions of growth in the Latin American countries, which reflect the effects of the economic downturn that followed the East Asian crisis and the 2008 financial crisis, respectively. This result shows that the dynamic of growth in Latin American economies is particularly vulnerable to external slowdowns and tightening of world financial conditions. In the case of Nordic countries, shocks in corruption have played a relevant role in explaining growth with the sole exception of Denmark, which is the most transparent

Nordic country and, in fact, the most transparent country in the world according to Transparency International (2019). In the case of the other Nordic countries, it is found that, although they are also highly transparent, they have been affected during the study period by some relevant instances of corruption which, in turn, generate notorious impacts on the economic dynamic precisely because they have a high level of transparency. For instance, in the case of Finland, the influence of corruption is more noticeable until 2008, which is in line with the fact that during the years before to the crisis there were corruption issues in the financing of political campaigns (see Group of States against Corruption, 2007). In Iceland the influence of corruption on growth is more noticeable between 2004 and 2008, which is consistent with the fact that this economy was particularly affected by corruption and the subsequent political instability in the context of the financial crisis. In the case of Norway, corruption issues have been identified in municipalities, in particular in relation to building, planning and maintenance. In addition, several large companies in which Norwegian government owns substantial stakes have faced corruption charges and there have also been cases of corruption in the relationship between the government and multinational companies, like that involving Siemens and the Norwegian Department of Defense; see Smith et al. (2013). On the other hand, the effect of the economic contractions in 1999 and 2009 is also verified in the dynamic of growth of Nordic countries. It can be noted that they were strongly affected by the 2008 financial crisis, even more than the Latin American ones.

Figure 8 shows that corruption has noticeably affected human development in all Latin American countries, including Brazil and Peru. This implies that in Latin America corruption has affected human development in dimensions beyond per capita income and is consistent with the fact that, although Latin American countries have enjoyed good economic growth in the last years, they still have important limitations in aspects related to human development like income distribution, education, healthcare, poverty reduction, etc. On the other hand, shocks in corruption have also played a perceptible role in explaining the dynamic of human development in Nordic countries. In the case of Iceland, it is observed that corruption noticeably affected human development in the years previous to the financial crisis, but its influence was less important after the crisis. This is consistent with the study of Nyblom et al. (2019) in the sense that citizens' demands during the financial crisis have been effective in attaining policy measures to guarantee the conditions of the Icelandic welfare state. In addition, it is observed that the human development of most of countries in both regions was negatively affected as consequence of the Great Recession, especially in 2009. This can be explained by the fact that the crisis affected not only income but also other aspects directly related to human development like health and education since several governments had to reduce social spending due to the tightening of fiscal conditions.

Figure 9 shows that the dynamic of natural resources exports has been driven by its own shock to a great extent in all cases. This result can be expected since the dynamic of the natural resources sector depends mainly on factors specific for this sector like endowments, discovery of resources, extraction methods, etc. It is also observed that shocks in the export price index have played a remarkable role in explaining the dynamic of natural resources exports both in Latin American and Nordic countries. This is consistent with the fact the dynamic of natural resources exports follows the evolution of commodity prices. In this way, Latin American and Nordic economies have benefited from the global commodities boom, mainly due to the rising demand from emerging markets; see Kristjanpoller et al. (2016). Additionally, in several countries from both regions is observed a certain contraction of natural resources exports between 2012 and 2016 and then an increase in 2017. This is consistent with the dynamic of commodity prices which, after reaching a peak in 2010-2012, went down until 2016, having a subsequent recovery in 2017. It is also found that there was a noticeable contraction of the natural resources sector in 2009 in all Latin American and Nordic countries. This shows that this sector is clearly vulnerable to external conditions, which can be expected since it depends on external demand. Besides, shocks in corruption have played a perceptible role in explaining the dynamic of natural resources exports, especially in Bolivia and Iceland. In the case of Bolivia this effect is more noticeable during the period 2001-2006 in which there were corruption issues in oil contracts.

1.4.3. Robustness Analysis

Here it is analyzed how the results of the baseline model are sensible under different conditions. In order to save space, all Figures (IRF, FEVD, HD) are available upon request.

Alternative Values for the Hyperparameters

Alternative values of the hyperparameters are assumed. So, it is considered a model with higher cross-variable weighting and lower lag decay so that $\lambda_2 = \lambda_3 = 0.8$.

In terms of the IRFs, the responses of economic growth, human development and natural resources exports to shocks in corruption are qualitatively and quantitatively similar to the baseline model for both Latin American and Nordic countries.

The results of the FEVD are also in line with those of the baseline model since the importance of corruption in explaining fluctuations in growth in Bolivia and Chile, in the case of Latin America, and in Norway and Iceland, in the case of Nordic countries. In turn, shocks in corruption have some influence in explaining fluctuations of human development and natural resources exports.

The HD shows patterns like those in the baseline model, so that corruption plays a noticeable role in explaining the dynamic of growth in Bolivia, Chile and Colombia, in the case of Latin American countries, and in Finland and Iceland, in the case of the Nordic ones, especially in the periods before the financial crisis. The results of the HD of human development and natural resources exports are also quite similar to those in the baseline model.

Alternative Specification of Priors

As Jarociński (2010) explains, there is extensive discussion about the problem of specifying non-informative priors for the variance of the coefficients. So, following Gelman (2006), it is implemented an alternative specification by setting a less informative prior given by a uniform prior for the standard deviation, which translates into a prior for the variance as $p(\lambda_1) \propto \lambda_1^{-\frac{1}{2}}$.

Concerning IRFs, the responses of growth to shocks in corruption are like those in the baseline model in all countries with the exception of Chile, where the effect becomes insignificant. So, the result for Chile is not robust and this is in line with the fact that the initial response of natural resource exports (which represent an important source of growth in the Chilean economy) to shocks in corruption is insignificant in this country. It is found again that corruption has a negative impact on human development in all countries.

Corruption has a positive impact on natural resources exports in Latin American countries although, unlike the baseline model, this effect, albeit positive, becomes not persistent in the case of Colombia. In the case of Nordic countries, the impact of corruption on natural resources exports remains negative.

With respect to the FEVD of growth, the importance of shocks in corruption in accounting for fluctuations of growth in Bolivia is somewhat less than in the baseline model. The increasing role of corruption in explaining fluctuations of growth in Nordic countries is found again. As regards the FEVD of human development, the results are similar to those in the baseline model, although the influence of corruption becomes more notorious in the case of Norway. The FEVD of natural resource exports clearly resembles the baseline model.

The results of the HD of economic growth are similar to those in the baseline model, although under this alternative specification shocks in corruption have somewhat less importance. In turn, shocks in corruption have played a perceptible role in explaining the dynamic of human development in Latin American and Nordic countries, although in the latter the influence of corruption is somewhat higher as compared with the baseline model, especially in the case of Iceland. The HD of natural resources exports is quite similar to the baseline model.

Alternative Ordering of the Variables

Our scheme of identification is based on contemporaneous restrictions which assume a specific ordering of the variables. Given this, it is considered the alternative ordering: $Y_{it} = [y_{1it}, y_{2it}, y_{3it}, y_{5it}, y_{4it}]'$.

In terms of the IRFs, the responses of growth to shocks in corruption are like those in the baseline model for Latin American and Nordic countries, although in the case of Brazil the impact of corruption on growth becomes slightly negative in some periods. It is found again that corruption have a negative impact on human development in all cases, but this effect becomes less significant in Nordic countries, which can be due to the fact that their welfare states are well-established and, consequently, are less susceptible to changes in corruption. The responses of natural resources exports to shocks in corruption resemble the baseline model.

The results of the FEVD of economic growth, human development and natural resources exports show the same patterns that the baseline model. The only noticeable difference is that shocks in growth have more influence in explaining fluctuations of human development, especially in Brazil, Iceland and Norway.

The results of the HD of economic growth, human development and natural resources exports are qualitatively and quantitatively similar to the baseline model. Nevertheless, under this alternative specification, shocks in growth have certain influence in explaining the dynamic of human development across countries. This change can be expected precisely because this alternative ordering considers human development as the most endogenous variable.

1.5. Alternative Approaches

Two alternative approaches are presented for our analysis by considering long run relationships and asymmetric effects[2]. In each case, three results are considered: (i) the full panel of ten countries, (ii) the panel of Latin American countries, and (iii) the panel of Nordic countries.

A Panel Error Correction VAR Model

A panel error correction VAR model is used for evaluating the short- and long-run relationships among the variables. Firstly, applying the panel unit root tests developed by Im, Pesaran and Shin (2003), Breitung (2000), and Maddala-Wu (1999), it is found that the variables present unit roots at levels but they are stationary at first differences in all cases. Secondly, the panel cointegration tests proposed by Pedroni (1999), Kao (1999) and the Fisher-type panel cointegration test based on Johansen's methodology (see Maddala and Wu, 1999) are applied. The null hypothesis of no cointegration is rejected in all cases suggesting that there is one cointegrating relationship. Then, panel cointegrated regressions are estimated by means of Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) - see Phillips and Hansen (1990) and Stock and Watson

[2] For the sake of brevity, the analysis will focus on the IRFs, but the other results are available upon request.

(1993), respectively. The results are similar for the full sample and the Latin American and Nordic countries. In this way, in the long-run, human development and natural resources exports significantly increase GDP per capita. In turn, there is a negative relationship between corruption and GDP per capita, which implies that corruption is definitively harmful for economic performance in the long run.

Short- and long-term causality among the variables is tested with the panel error correction VAR model. In the case of the full sample, there is a causal relationship from corruption to economic growth in the short term. There is also noted that natural resources exports growth cause economic growth in the short term, which can be expected because in most of countries of our sample natural resources exports represents a substantial proportion of total export basket. In turn, there is bidirectional causality between natural resources exports and human development in the short term. On the other side, since the error correction coefficient is negative and significant in the equations of GDP per capita, human development and the natural resources exports, it can be affirmed that there is long-run causality from the variables of our system to those three variables. In the case of the Latin American countries, the results are similar to those of the full sample. However, it is observed in this case that, while corruption does not cause economic growth in the short term, it does cause natural resources exports, which confirms the close relationship between corruption and extractive industries in Latin America; see Gudynas (2017). By contrast, in the case of the Nordic countries it is noted that corruption does have a short-run causal influence on economic growth. However, unlike the case of the full sample and Latin American countries, corruption does not cause economic growth in the long term in Nordic countries.

Figure 10 shows the results of the IRFs, which are considered in terms of first differences for the sake of comparison with our other results. It is observed that economic growth has a negative response to shocks in corruption in the full sample and also in Nordic countries. Nevertheless, this response is not significant in Latin American countries. Similarly, shocks in corruption have a negative impact on human development growth, but this impact is only statistically significant in the full sample and in Nordic countries. In the case of the natural resources sector, the contrast between Latin American and Nordic countries is more notorious. While shocks in corruption has a noticeable positive impact in natural resources exports growth in Latin American countries, this impact is negative in the Nordic ones.

An Asymmetric Panel VAR Model

It is relevant to consider the possibility of asymmetric effects of the corruption shocks. This is because increases in corruption may be associated with dynamics which are different from those associated with decreases in corruption, which can be interpreted as increases in transparency. Consequently, the responses of the variables under consideration may be different between positive and negative shocks. Following the methodology of Simo-Kengne et al. (2013) and Shen et al. (2015), who consider asymmetric effects in a standard panel VAR framework, corruption is decomposed into two variables, one representing positive corruption changes and the other one representing negative corruption changes based on the Corruption Perceptions Index growth.

The results of the IRFs associated with positive corruption shocks are shown in Figure 11. It is observed that economic growth shows a significantly negative response to positive corruption shocks in the full sample, which is evidence for the sand the wheels hypothesis. The same is the case with Nordic countries, which is consistent with the idea that corruption would have a substantial negative impact on growth in countries with high institutional quality; see Aidt et al. (2008). By contrast, in Latin American countries the response of economic growth to shocks in corruption is not significant. Regarding human development growth, the results are in line with our previous findings since positive corruption shocks have a negative impact in the human development index growth in the full sample and also in Latin American and Nordic countries. This result can be expected since more corruption negatively affects dimensions of human development like education and healthcare; see Mauro (1998), Gupta et al. (2001), Ortega et al. (2016). It must be noted that this impact is only statistically significant in the first period. In turn, it is observed that in the full sample natural resources exports growth have a negative response to positive corruption shocks in the first period but then it becomes insignificant. In the case of Latin America, positive corruption shocks significantly increase activity in the natural resources sector since the second period. By contrast, in Nordic countries positive shocks in corruption significantly deter natural resources exports.

The results of the IRFs associated with negative corruption shocks are shown in Figure 12. There is evidence of asymmetric effects since in several cases the responses to positive corruption shocks differ from the respective responses to negative corruption shocks. Thus, in the full sample, the response of economic growth to negative corruption shocks is not significant in any period. Besides, in Latin American countries negative corruption shocks have a significantly positive impact on economic growth in the first period and, consequently, Latin American countries may spur economic growth by increasing the transparency of their institutions and procedures; see Engel et al. (2018). In Nordic countries the response of economic growth to negative corruption shocks is not significant. This is consistent with the fact that in Nordic countries increases in transparency do not necessarily imply a substantial difference for economic agents since they already have a high level of transparency. On the other hand, negative corruption shocks have a positive impact on human development growth in the full sample and also in Latin American countries. This is consistent with the idea that more transparency improves the quality and efficiency of public spending associated with the promotion of human development; see Fukuda-Parr et al. (2011). Regarding the natural resources sector, it is noted that negative corruption shocks have a positive but not significant impact on natural resources exports in Latin America. So, it seems that activity in the natural resources sector is fostered more by corruption than by transparency in this region. In turn, negative corruption shocks do not have a significant impact on natural resources exports in Nordic countries. In this way, our analysis of asymmetric effects shows a revealing pattern, namely, that in Nordic countries, while positive corruption shocks have a negative impact, negative corruption shocks do not have a significant impact. This is in line with our previous argument that more corruption does imply a substantial and negative alteration in the way in which Nordic economies normally operate, so that departures from transparency remarkably affect important aspects like the confidence of economic agents. By contrast, increases in transparency do not represent a substantial alteration in this regard since Nordic countries are already recognized as the most transparent in the world.

1.6. Conclusions

In the academic literature there are considerable debate about the effects of corruption on economic growth, human development and the natural resources sector. Thus, there are discussions about the sand the wheels versus the grease the wheels hypotheses, the impacts of corruption on human development, and corruption issues in the extractive industries. This paper contributes to these discussions by presenting evidence for Latin American and Nordic countries. The analysis is conducted by estimating a hierarchical Bayesian panel VAR model given that this method allows us to use efficiently the information by exploiting the heterogeneity across countries.

The results reveal some relevant contrasts between Latin American and Nordic countries. In Latin America there is mixed evidence regarding the impact of corruption on growth since there is support for the sand the wheels hypothesis in Bolivia and Chile, support for the grease the wheels hypothesis in Colombia and no significant impact of corruption on growth in Brazil and Peru. By contrast, the response of growth to shocks in corruption is significantly negative in all Nordic countries. In turn, it is found that shocks in corruption negatively affect human development in all countries from both regions. Corruption tends to spur natural resources sector in Latin American countries, especially in Brazil, Colombia and Peru, which suggests that corruption could be "facilitating" extractive operations in these countries. By contrast, corruption is detrimental for the activity of the natural resources sector in all Nordic countries. Then, robustness checks were applied considering alternative specification of hyperparameters, priors and ordering of the variables. It is found that most of the patterns observed in the baseline model remain under these new specifications.

In addition, two alternative methodological approaches are considered. Firstly, a panel error correction VAR model is estimated and it is found that in Latin American countries corruption does not cause economic growth but it does cause natural resources exports. Besides, in Nordic countries corruption have a causal impact on economic growth. Secondly, asymmetric effects are introduced by distinguishing between positive and negative shocks in corruption. The results corresponding to positive corruption shocks are in line with those of our baseline model. In turn, the results corresponding to negative corruption shocks show interesting patterns. In Latin American countries negative corruption shocks have a significantly positive impact on economic growth, so that these countries may spur economic growth by increasing the transparency of their institutions and procedures. By contrast, in Nordic countries negative corruption shocks do not have a significant impact, which is consistent with the idea that increases in transparency do not represent a substantial alteration for these countries since they are already recognized as the most transparent in the world.

In terms of policy recommendations, the results of this paper suggest that Nordic countries must continue to strive to avoid corruption because, precisely due to their high level of transparency, increases in corruption represent a substantial alteration regarding how they normally operate and, consequently, become particularly harmful for these economies. In turn, Bolivia and Chile could increase their level of economic growth by reducing corruption given that evidence for the sand the wheels hypothesis is found in these countries. In turn, special attention should be given to corruption issues in the natural resources sector of Brazil, Colombia and Peru, where natural resources exports respond positively to shocks in corruption. In addition, regardless the issue of the "grease" versus the "sand the wheels" debate, governments should seek to reduce corruption because, despite corruption can have mixed effects on economic growth in some contexts, it is anyway harmful for human development.

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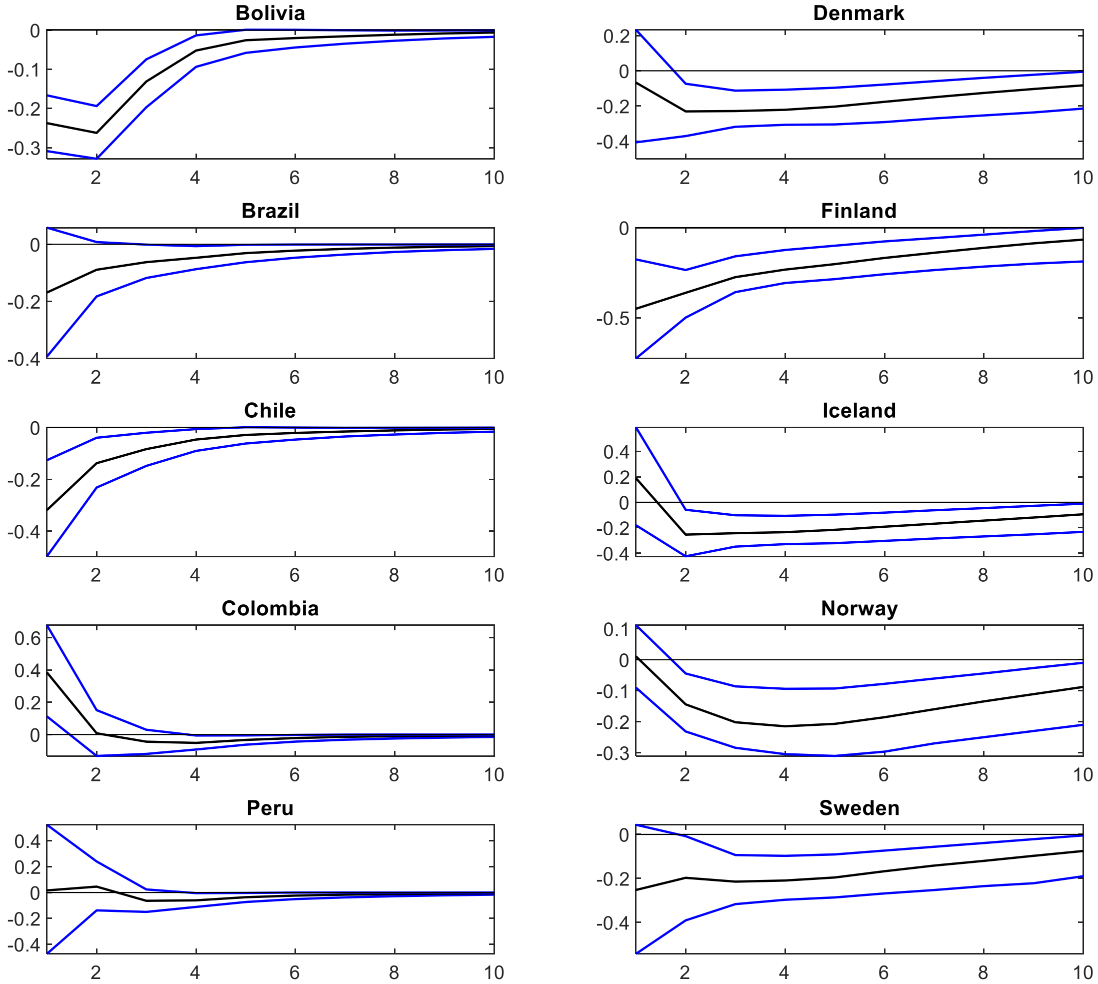

Figure 1. Median IRFs of Output Growth to Shocks in Corruption

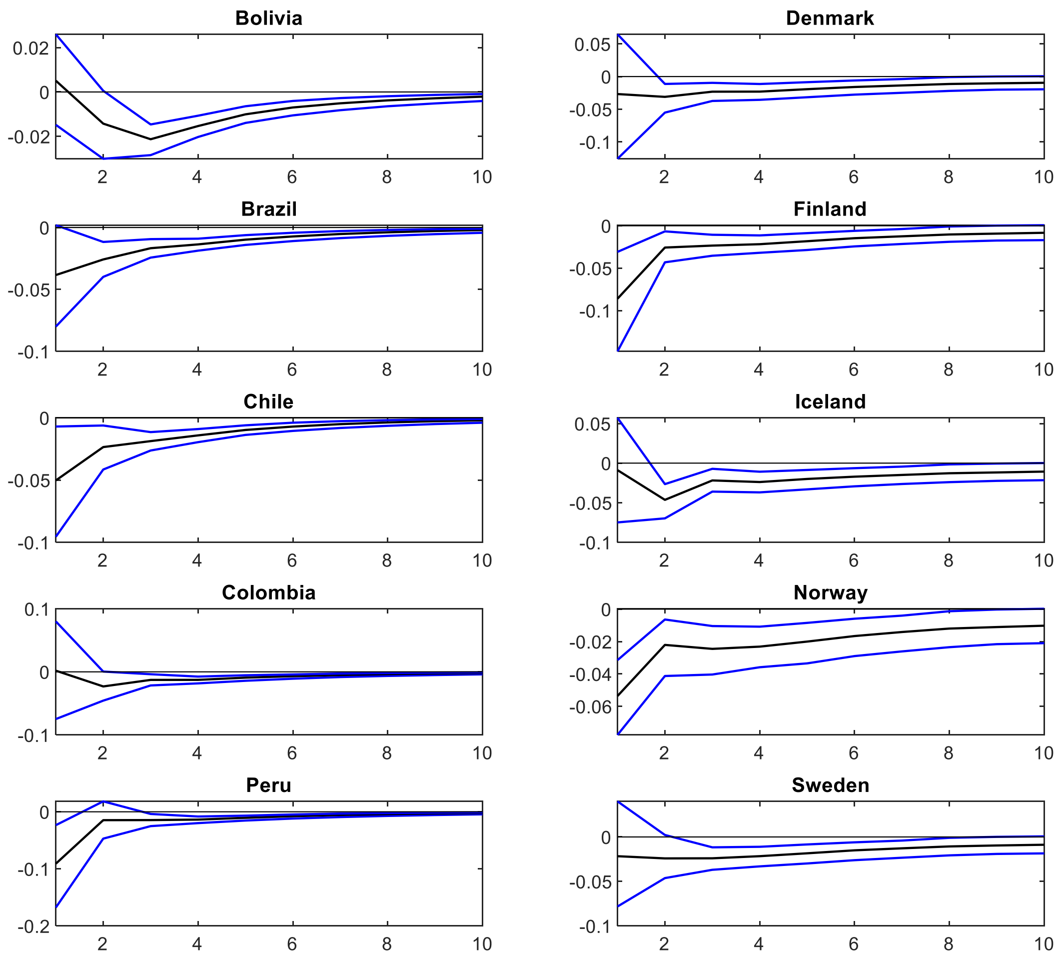

Figure 2. Median IRFs of Human Development Index Growth to Shocks in Corruption

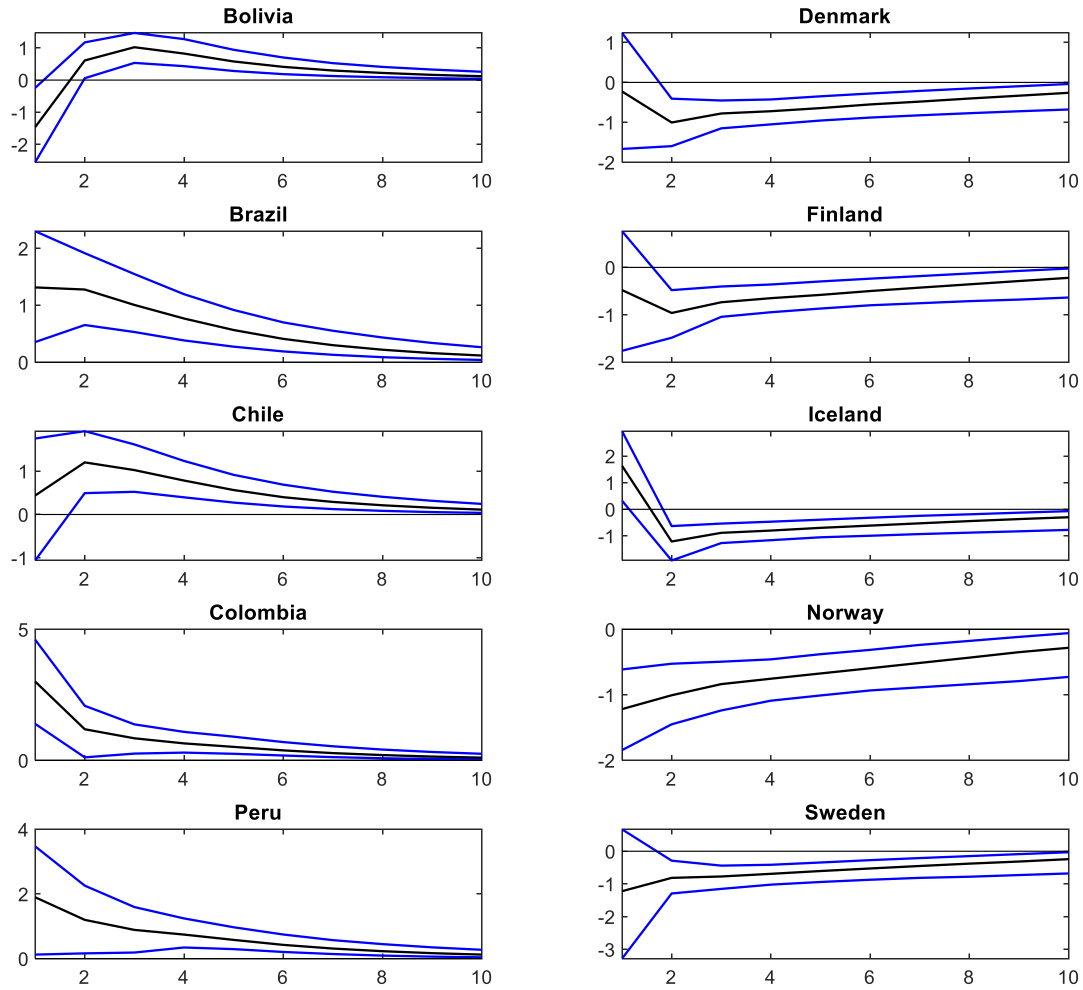

Figure 3. Median IRFs of Natural Resources Exports Growth to Shocks in Corruption

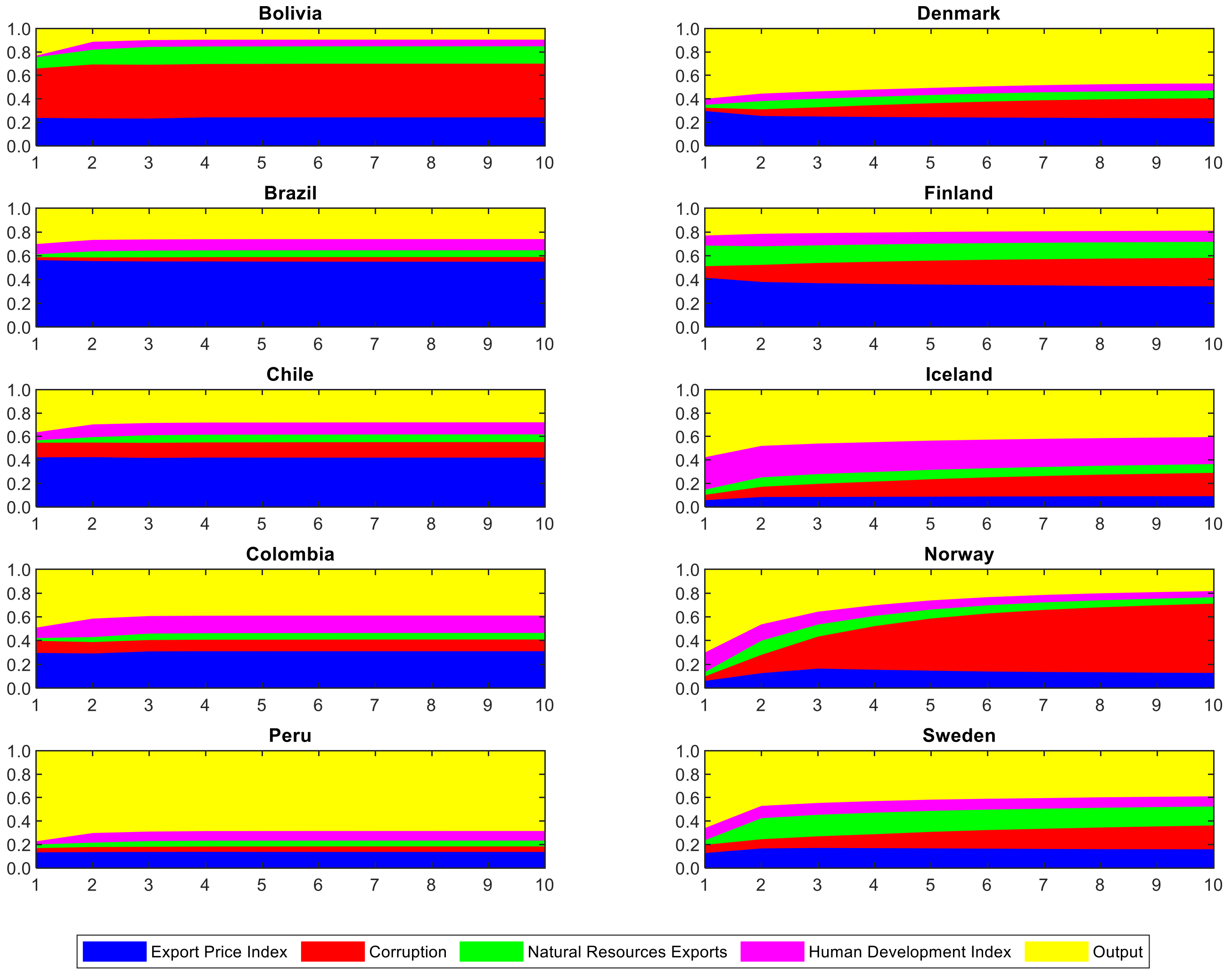

Figure 4. FEVD of Output Growth

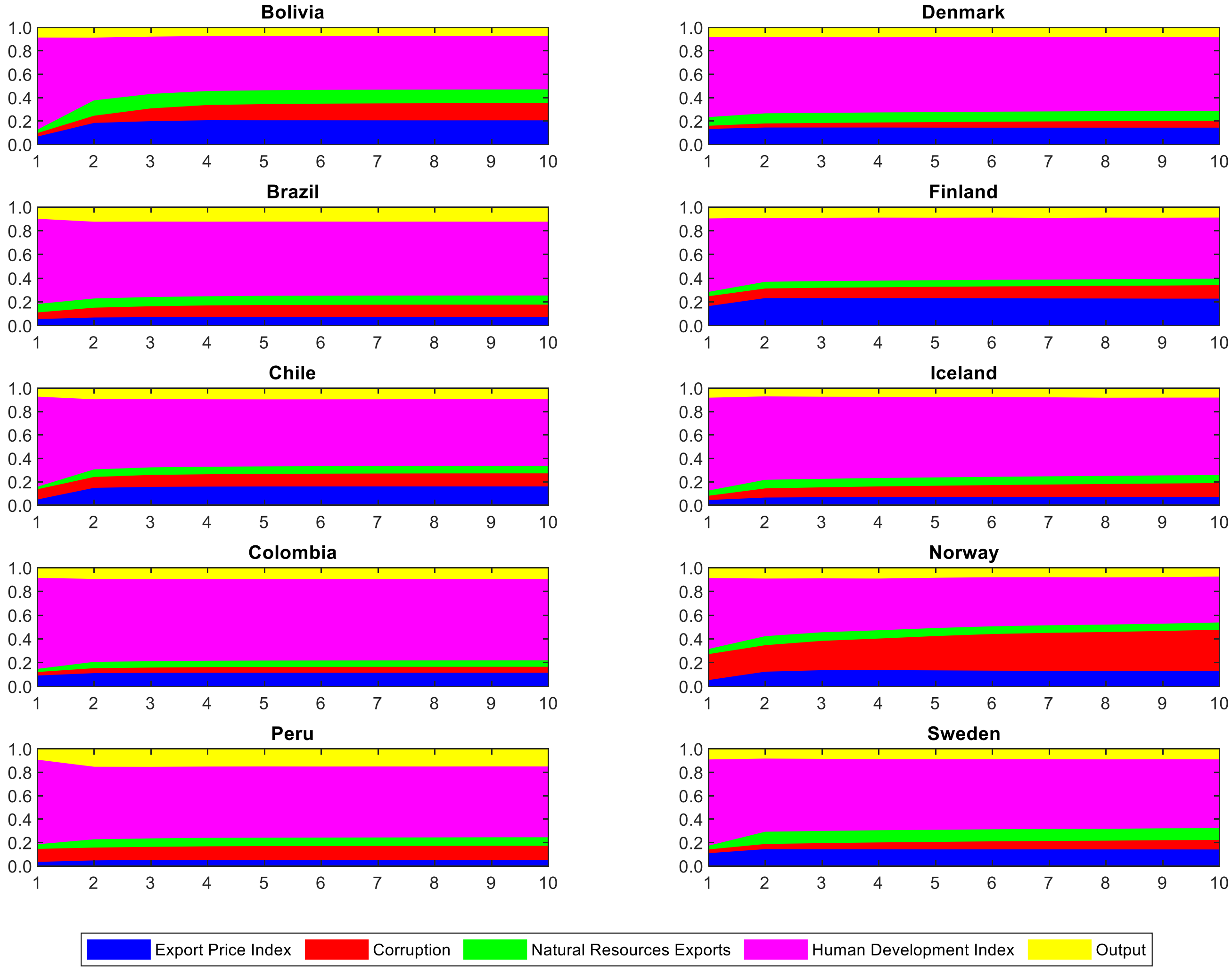

Figure 5. FEVD of Human Development Index Growth

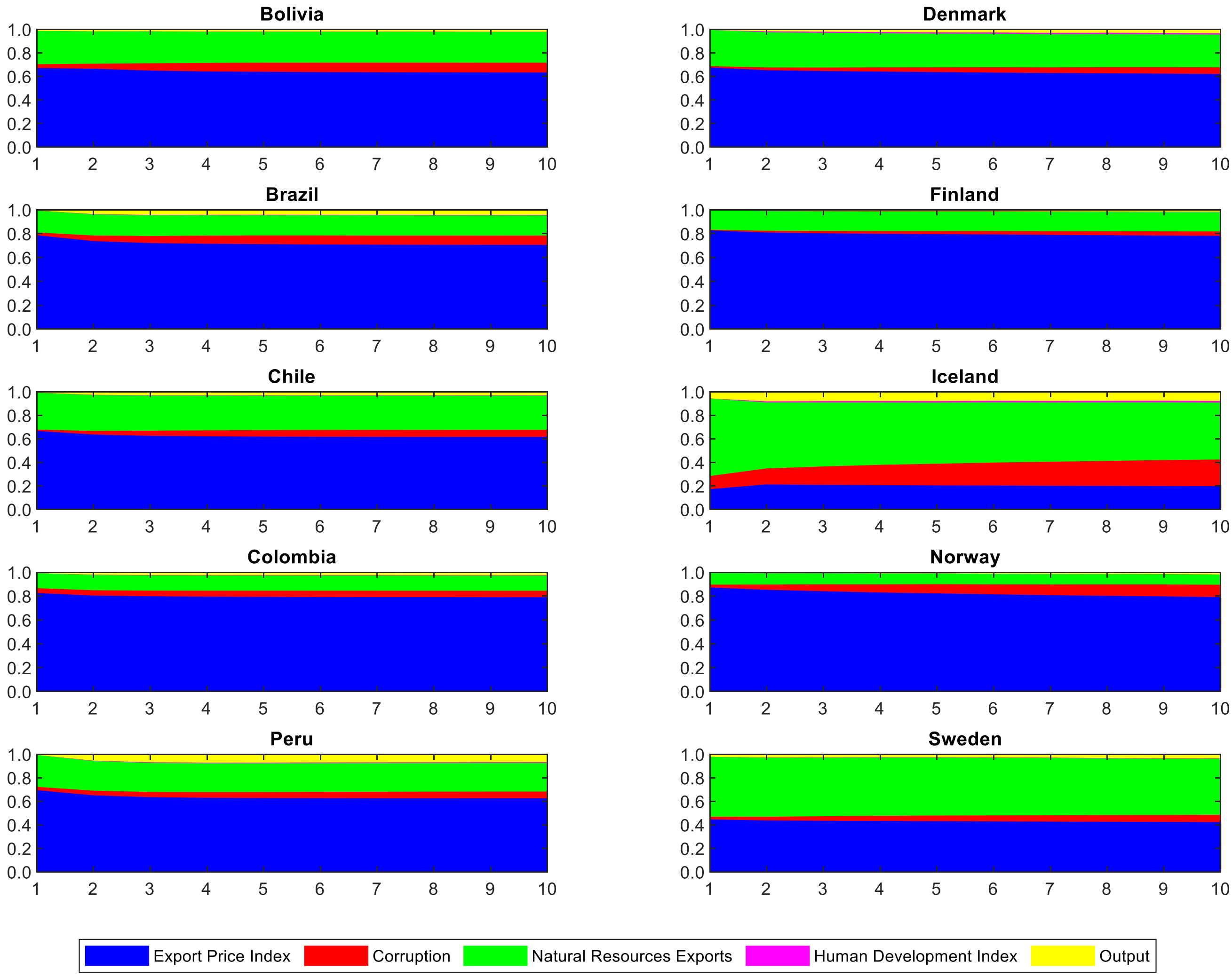

Figure 6. FEVD of Natural Resources Exports Growth

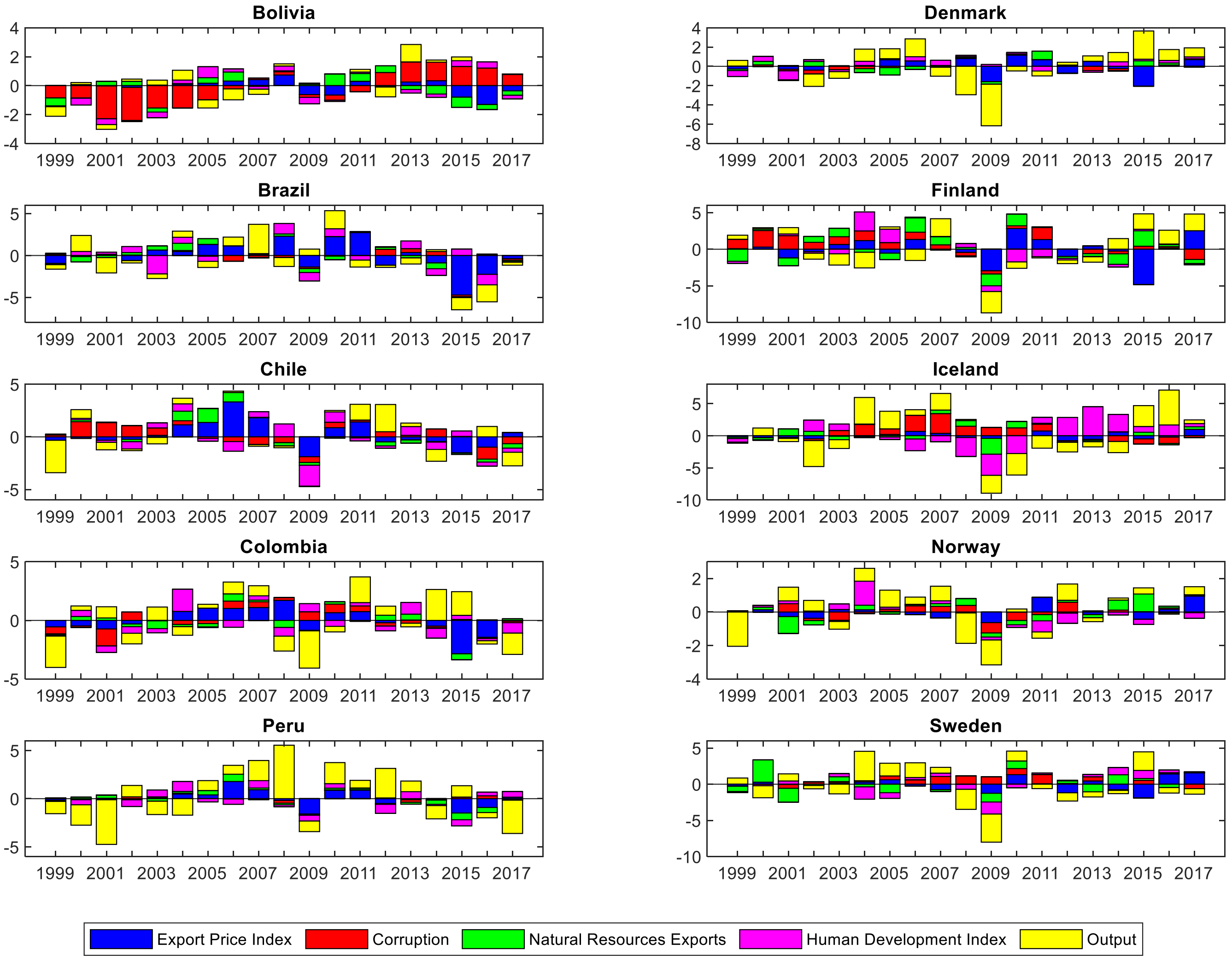

Figure 7. Historical Decomposition of Output Growth

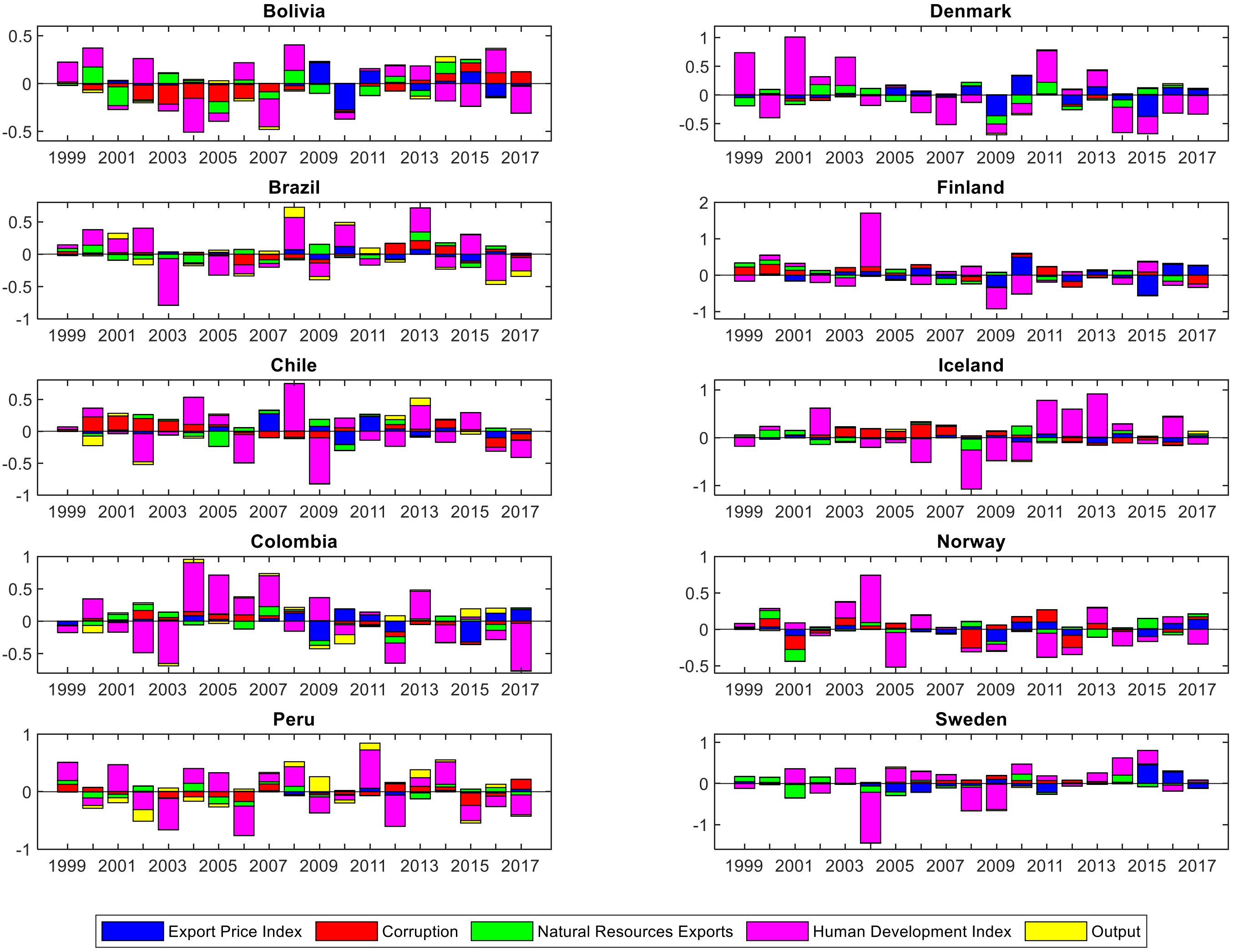

Figure 8. Historical Decomposition of Human Development Index Growth

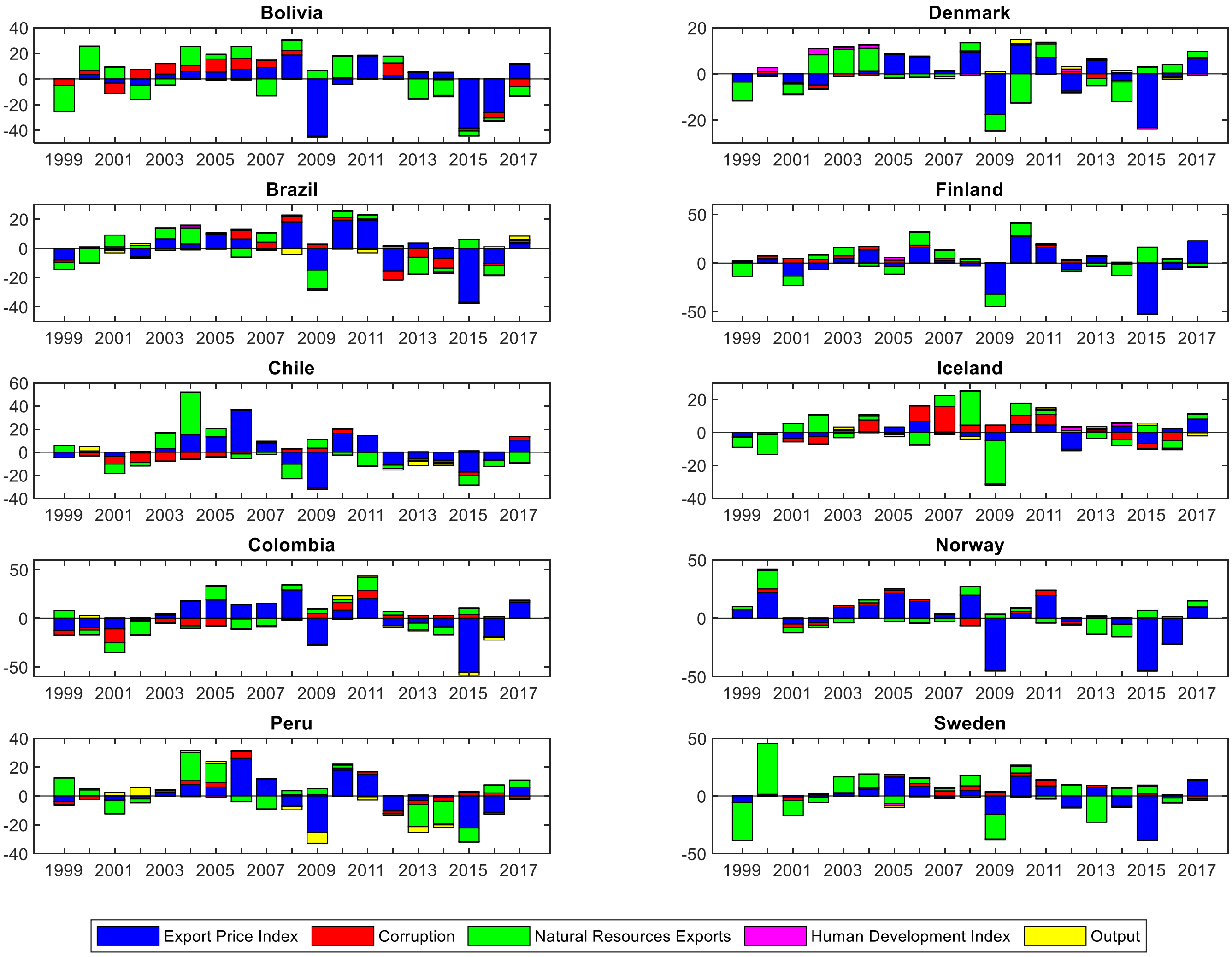

Figure 9. Historical Decomposition of Natural Resources Exports Growth

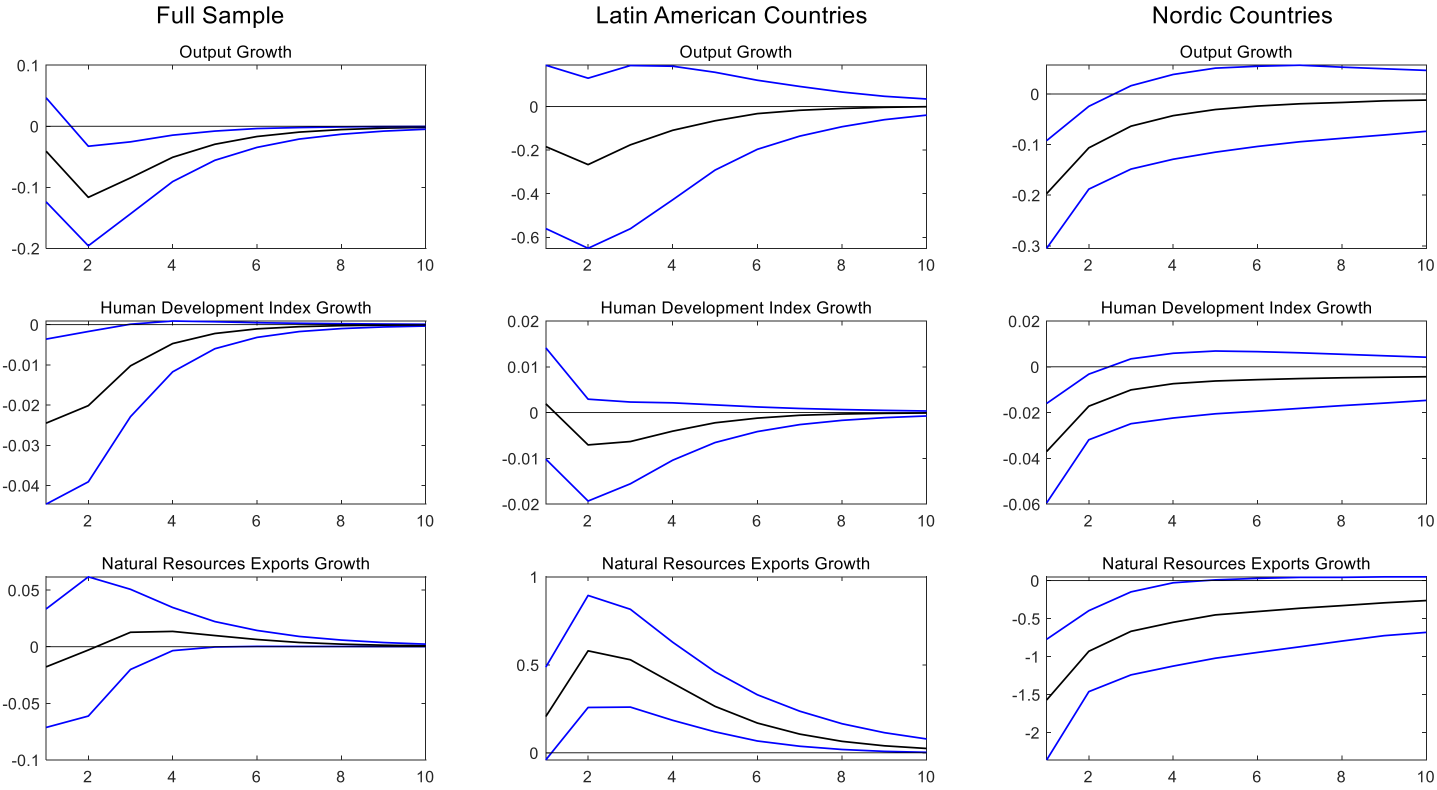

Figure 10. Mean IRFs in Panel Error Correction VAR Model: Shocks in Corruption

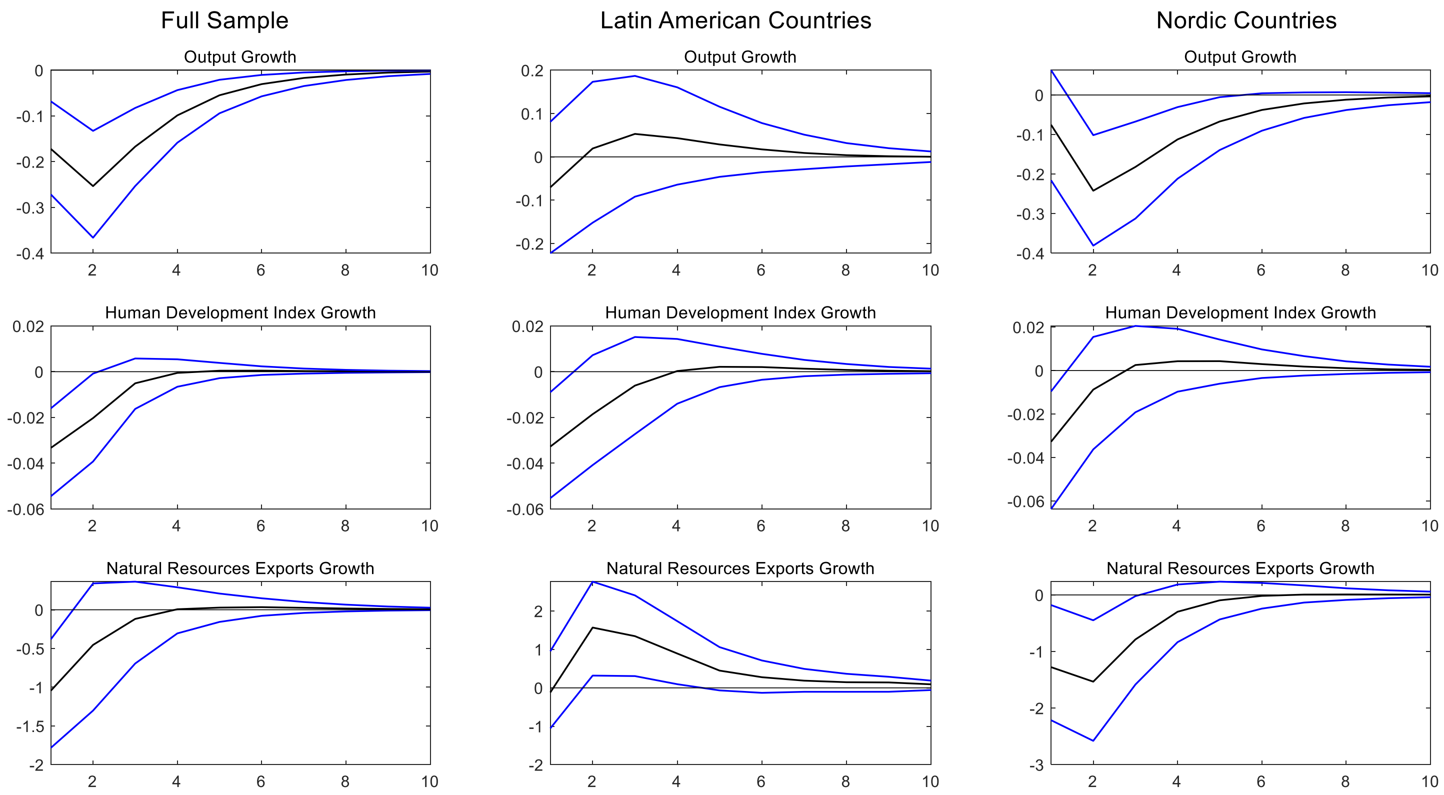

Figure 11. Mean IRFs in Asymmetric Panel VAR Model: Positive Corruption Shocks

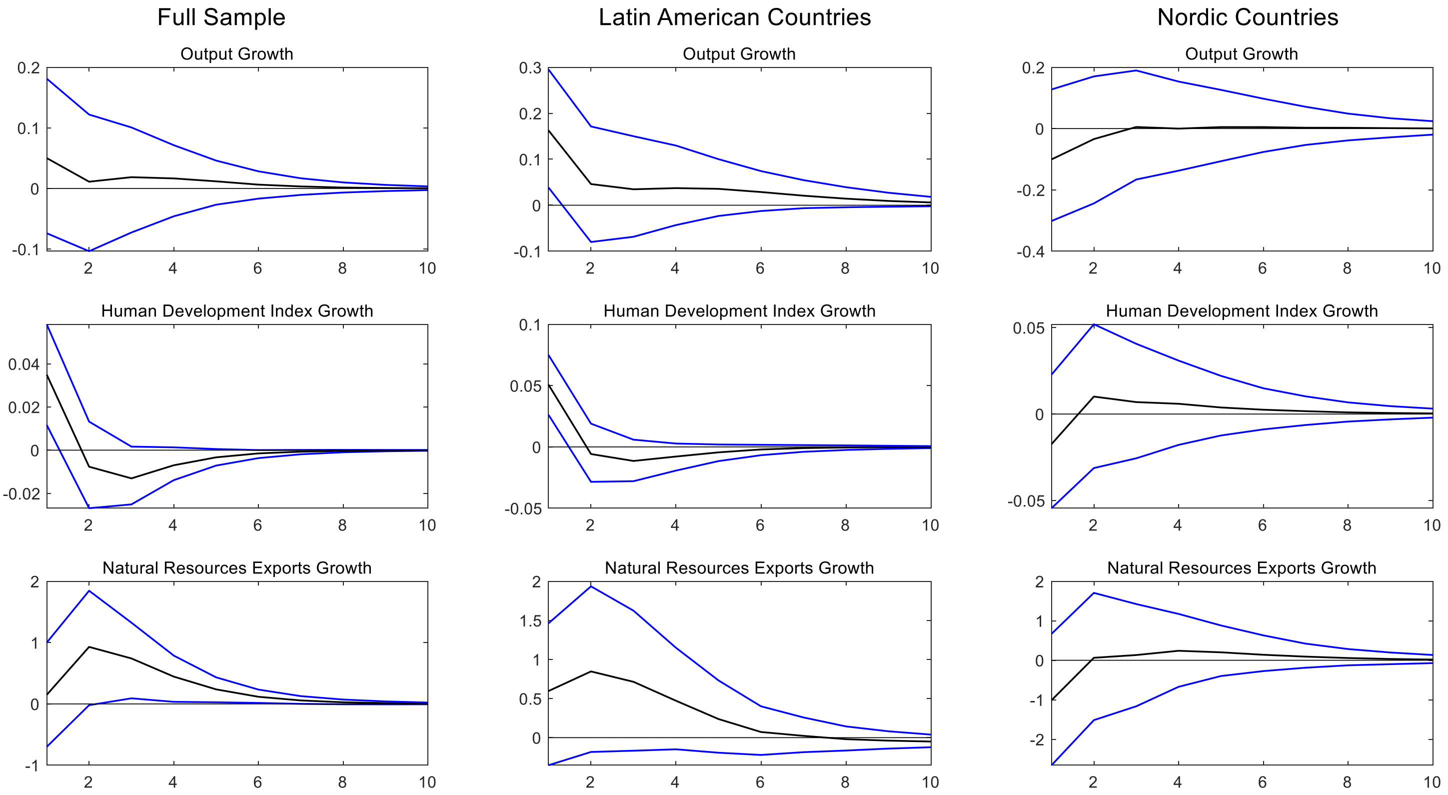

Figure 12. Mean IRFs in Asymmetric Panel VAR Model: Negative Corruption Shocks

CHAPTER 2: Evolution of the Effects of Mineral Commodity Prices on Fiscal Fluctuations: Empirical Evidence From TVP-VAR-SV Models for Peru

ABSTRACT. This paper studies the evolution of the effects of fluctuations in mineral commodity prices on fiscal variables, especially those associated with fiscal revenues, in Peru by means of VAR models with time-varying parameters and stochastic volatility (TVP-VAR-SV). Different alternative specifications are compared using the marginal likelihood and the deviance information criterion, which show that it is essential to consider stochastic volatility. It is found that an increase of 1% in the growth of mineral commodity prices generates increases of around 1.5% and 2.5% in the growth of taxes from mining and mining canon, respectively, thus reflecting a remarkable sensitivity of these variables to external shocks. In turn, these responses are increasingly more pronounced until reaching a peak around 2009 and then decrease, which is in line with the dynamics of the commodities boom. In the variance decomposition, the importance of shocks in mineral commodity prices in explaining fluctuations in taxes from mining and mining canon increases in line with the increasing tendency of mineral prices until the Great Recession, where shocks in mineral commodity prices explain between 40% and 50% of fluctuations in taxes from mining and mining canon, and then it is reduced. This shows the importance of allowing time-varying parameters and stochastic volatility in contrast with a standard VAR.

2.1. Introduction

The dynamics of commodity prices constitutes an important issue for the development of resource dependent countries since it affects not only the real activity but also fiscal variables. Shocks in commodity prices can generate noticeable fluctuations in tax revenues from the natural resources sector, which in turn generates uncertainty about the availability of funds for government spending, thus affecting fiscal policy, social services and public investment. When commodity prices are rising, as in the commodities boom, tax revenues have substantial increases and this can lead to overspending, which aggravates fiscal procyclicality. In turn, when commodity prices are decreasing, as during the Great Recession or at the end of the commodities super cycle, government revenues and expenditures also tend to decrease. Consequently, several resource-rich economies have adopted different fiscal policy rules in order to reduce the impact of commodity price fluctuations on fiscal variables. Nevertheless, the results are not always as expected since the fiscal rules may be too lax or are not followed in practice.

This problem is particularly relevant for mineral-dependent economies. As García and Guzmán (2019) note, the commodity price volatility is a critical characteristic of mineral markets since many mineral commodities fluctuate remarkably in the short term and, in fact, it is not unusual for mineral prices to double or fall by half within a year or two. This has motivated research on the fiscal effects of fluctuations in international prices in mineral economies like Chile, Niger and Zambia; see De Mello (2008), Adam and Simpasa (2010), De Gregorio and Labbé (2011), Go et al. (2016).

In the case of Peru, it is an economy in which the mining sector is clearly relevant. Mining accounts for nearly 10% of Peruvian GDP and 60% of Peruvian total exports; see Ernst & Young Peru (2019). This is similar to the case of Chile, another relevant mining country, where the mining sector accounts for around 10% of GDP and 55% of total exports; see Videla (2019). In fact, Peru is a significant global mining player since it is among the largest producers of copper, silver and zinc around the world. In turn, it is the largest exporter of copper to China, which is the world's largest consumer of this metal. Besides, Peru scores 80.1 out of 100 in the Mining Contribution Index, which measures the relative importance of mining to the economy of a country, so that it is qualified as resource-dependent. In this way, according to Consejo Fiscal (2019), the dependence on commodity prices, especially mineral prices, is the main intrinsic characteristic of Peruvian economy, both in macroeconomic and fiscal terms. Given this, Peru constitutes an appealing case to study the fiscal effects of mining dependency.

It is also important to note that there have been important changes in the fiscal framework in Peru. On 1 January 2000 the Law of Fiscal Prudence and Transparency (Law N° 27245) came into effect with the objective of ensuring fiscal balance by reducing public debt and avoiding deficits in periods of recession. Furthermore, considering the importance of stability in public finances, the Law N° 27245 was substituted by the Law to Strengthen Fiscal Responsibility and Transparency (Law N° 30099) which came into effect on 1 January 2015 with the objective of guaranteeing the stability in government spending by financing it with structural fiscal revenues, thus sheltering public finances from volatility in commodity prices. Besides, Mendoza and De Echave (2016) show that there have been relevant changes in the taxation of the Peruvian mining sector. In turn, there were also changes in the mining canon, which is defined as fiscal revenues from mining activity that are destined for regions and localities where mining exploitation takes place with the aim of promoting their economic and social development. As Aspillaga (2006) reports, between January 1997 and May 2002 the mining canon was 20% of the income tax from the holders of the mining activity but from June 2002 this percentage was raised to 50% in accordance with Law of Canon (Law N° 27506).

Given this, the present paper adds to the literature by analyzing the evolution of the effects of mineral commodity prices on fiscal variables in the Peruvian economy by means of a time-varying parameters vector autoregression with stochastic volatility (TVP-VAR-SV). In specific, our study is primarily focused on analyzing the impacts of shocks in mineral commodity prices on fiscal revenue variables, namely, taxes from mining and mining canon. The application of a TVP-VAR-SV methodology is particularly suitable for our purpose as compared with the conventional constant VAR approach. First, because there have been important changes in the economic context, so that the possibility of parameters with changes over time should be considered. Second, because it would be unreasonable to assume that volatility is constant in a model that incorporates variables with a remarkable and changing volatility like mineral commodity prices. In this way, the results show that considering stochastic volatility is essential in order to properly capture the dynamics of the system. In turn, it is found that the responses of taxes from mining and mining canon to shocks in mineral commodity vary over time so that they become increasingly more pronounced until reaching a peak around 2009 and then decrease. It is noted that these responses are more than proportional, thus reflecting a remarkable sensitivity of Peruvian fiscal revenues to external shocks. Besides, the importance of shocks in mineral commodity prices in explaining fluctuations in taxes from mining and mining canon increases until reaching a peak around 2009 and then decrease, which is in line with the dynamics of the commodities boom.

The remainder of this paper is organized as follows: Section 2 reviews the literature. Section 3 describes the methodology for estimation and model comparison. Section 4 presents the data and the empirical results with the respective interpretation and discussions. Section 5 concludes.

2.2. Literature Review

The debate about the impact of commodity price fluctuations on resource-dependent economies has been closely linked to the "natural resources curse"; see Auty (1993). From this perspective, the abundance of resources, instead of being a blessing, would be a curse for countries because it would lead to problems such as macroeconomic instability and unsustainability growth.

In this way, Hausmann and Gavin (1995) identify fluctuations in commodity prices as one culprit that hinders economic development in Latin America. Raddatz (2007) shows that the output effect of external shocks, such as commodity price fluctuations, is substantial in terms of the historical performance of low-income countries. In this vein, Cavalcanti et al. (2015) argue that volatility, rather than abundance per se, drives the resource curse. It must be considered that declines in commodity prices may have a very remarkable impact in resource-dependent economies. Thus, Christensen (2016) notes that the fall in commodity prices between 2014 and 2016 put the progress made by African countries in promoting sustainable development to a more serious test than did the 2008 financial crisis. In turn, Balashova and Serletis (2020) find that oil prices are procyclical and lead the business cycles in Russia.

Moreover, there are several studies focused on the impact of commodity price fluctuations on fiscal variables. Regarding government revenues, commodity price fluctuations translates into uncertainty about tax collection in resource-dependent countries since fiscal revenues tend to have remarkable increases during periods of increasing commodity prices, but they may also be substantially affected by abrupt reductions in those prices. So, fiscal fluctuations may act as a transmission mechanism for the resource curse; see Bleaney and Halland (2009). In this way, Claessens and Coleman (1991) note that tax revenues in Papua New Guinea have been very sensitive to commodity price changes. Furthermore, Jiménez and Tromben (2006) find that revenues from energy and minerals fluctuates much more than total revenues in Latin American countries.

The fiscal framework is also important regarding the relationship between commodity prices and fiscal fluctuations. Kumah and Matovu (2007) find that, under a context of uncertain commodity prices, countries have higher probabilities of meeting fiscal target if they follow a passive tax regime (in which tax decisions are taken in advance and independent of expenditure decisions) rather than an active tax regime (in which expenditure decisions influence tax decisions). In turn, De Mello (2008) finds that the compliance with the structural budget surplus rule has been successful in Chile since the correlation between the deviation of the price of cooper from its historical trend and the primary budget balance tends to decline over time. Medina and Soto (2016) show that when the Chilean government conducts fiscal policy in a way such that the government saves most of the extra revenues from higher cooper prices, the macroeconomic fluctuations are less severe.

There is clear empirical evidence that commodity prices have an important influence in fiscal revenues. Thus, Sinnot (2009) finds that in Latin American countries there is a positive fiscal revenue response to commodity price changes and that fiscal revenues from mining have risen significantly during the period 1998-2008. Spatafora and Samake (2012) find that tax revenues rise in response to commodity price increases in a panel of 116 countries during the period 1990-2010. Ehrhart and Guerineau (2013) show that tax revenues are significantly affected by the volatility of commodity prices in a sample of 80 developing countries over the period 1980-2008. Céspedes and Velasco (2014) find that fiscal revenues seem to have risen strongly in tandem with the increase in commodity prices, especially in Latin America and the Middle East. Besides, Ossowski and Halland (2016) note that in several resource-rich countries fiscal vulnerability to resource shocks increased during the resource price boom, so that they were strongly affected when prices decreased. In turn, the impact of changes in commodity prices is more noticeable on the specific natural resources sector. In this way, Stella et al. (2019) find that in Nigeria changes in oil prices affected oil revenues leaving no significant impact on non-oil revenues, and Jones (2020) points out that mineral commodity prices are clearly a primary driver for mining tax revenue forecasting.

On the other hand, with respect to government spending, it must be considered that in countries with abundant natural resources, large royalties and windfalls are generated so that the problem of their use by the government is raised. Curry (1987) points out that revenues from mining can be used for promoting social development in mineral economies. However, a resource boom can often trigger an unsustainable increase in government spending, especially in the case of mineral discoveries in developing countries; see Leite and Weidmann (1999). Consequently, increasing commodity prices may be associated with fiscal procyclicality.

Empirical studies show mixed results in this regard. In the case of Latin American countries, both Jiménez and Tromben (2006) and Sinnott (2009) find that, although there has been a positive fiscal revenues response to rising commodities prices, this has not led to a matching rise in fiscal spending due to non-expansionary fiscal decisions and the establishment of new fiscal institutions. Besides, considering a panel of 121 countries, Aguirre and Giarda (2015) find that minerals are associated to the highest response of fiscal spending to changes in commodity prices beyond the cyclical stance of the economy. Medina (2016) analyzes the fiscal effects of commodity price fluctuations in Latin America and finds that the results are heterogeneous, with Venezuela having the largest response of government expenditures to commodity price shocks while in Chile expenditures respond very little, so that in countries with fiscal rules the responses are less pronounced. In turn, Zubikova (2019) finds that the fiscal policy of Nigeria and Mexico is significantly affected by fluctuations in commodity prices and that these countries have neglected public investment of their resource revenues. In contrast, Chile exhibits a strict compliance with its fiscal rule with a counter-cyclical fiscal policy and good management of its mineral revenues, and Botswana has used revenues from diamonds for public investments, although it has also been affected by the fall in commodity prices around 2015.

As pointed out by Auty (1999) and Orihuela and Echenique (2019), Peru is a relevant mineral economy. Some studies for the Peruvian case are described. Ahmad and García-Escribano (2006) note that mining canon constitutes a major and increasing source of revenues for Peruvian local governments. Cordano and Balistreri (2010) show that dependency on mining sector in Peru generates more volatile changes in the tax system, thus introducing distortions in the economy. Mendoza and De Echave (2016) show that the rise in mineral prices led to a boom in tax collection during the commodities boom, although the fiscal contribution of the mining sector decreased in the post boom phase. They also find that changes in tax system and the fall in commodity prices affected subnational governments by reducing the mining revenues that they perceive. Similarly, Jiménez et al. (2018) find that public investment in Peruvian local governments has been highly dependent on the canon from the exploitation of natural resources. Ganiko and Montoro (2018) show that the high volatility in the price of mining exports translates into unexpected fluctuations in Peruvian government revenues, making it difficult to forecast the other fiscal accounts. Besides, Mendoza (2019) studies the evolution of fiscal rules in Peru and shows that, while the first fiscal rules established limits on growth of non-financial expenditures of the general government and a fiscal deficit non greater than 1% of GDP, the new Fiscal Responsibility and Transparency Framework (Legislative Decree N° 1276) introduced additional rules like a public debt non greater than 30% of GDP and a more specific limit on growth of non-financial government expenditures in terms of the average of GDP growth in the last 20 years plus 1%. In turn, Jiménez and Rodríguez (2020), Meléndez and Rodríguez (2021) and Rodríguez and Santisteban (2021) analyze the impact of fiscal shocks on GDP and find that foreign shocks are also important in explaining fluctuations in real activity in Peru.

This paper contributes to the literature by presenting evidence about the evolution of the effects of mineral commodity prices on fiscal fluctuations in Peru. The analysis is performed by estimating a vector autoregression model that allows for time variation both in the VAR coefficients and the entire variance matrix of the shocks (TVP-VAR-SV); see Primiceri (2005). This represents an important methodological improvement regarding the previous literature which uses a VAR approach with constant parameters and constant volatility; see, for example, Kumah and Matovu (2007), Raddatz (2007), De Gregorio and Labbé (2011), Medina (2016).

Indeed, given that there have been important changes in the economic context (i.e., the Great Recession, the end of the commodities super cycle, changes in the fiscal framework, and changes in monetary policy) and there is a remarkable and changing fluctuation in the volatility of variables like mineral commodity prices, it is more adequate to consider a model with time-varying parameters and stochastic volatility. A major advantage of this model is that it allows to construct period-specific impulse-response functions (IRFs), which permits to evaluate how the response of fiscal revenue variables to shocks in mineral commodity prices may vary over time, which constitutes a relevant difference regarding studies that only consider an unique impact; see Spatafora and Samake (2012), Ehrhart and Guerineau (2013), and Stella et al. (2019). In addition, following Chan and Eisenstat (2018), the results of the model are compared with alternative specifications in order to assess the importance of allowing time-varying parameters and stochastic volatility.

2.3. Methodology

2.3.1. The Model

Following Chan and Eisenstat (2018), it is considered a TVP-VAR-SV model which allows time-variation in the VAR coefficients and the variance of the shocks. In this way:

$$B_{0,t}y_t = \mu_t + \sum_{i=1}^{p} B_{i,t}y_{t-i} + \epsilon_t,$$

where $B_{0,t}$ is an $n \times n$ lower triangular matrix of contemporaneous effects with ones on the diagonal, y_t is an $n \times 1$ vector of observations, μ_t is an $n \times 1$ vector of time-varying intercepts, B_{it} is an $n \times n$ matrix with the parameters of the lagged variables, and ϵ_t is an $n \times 1$ vector of heterocedastic errors such that $\epsilon_t \sim N(0, \Sigma_t)$, where $\Sigma_t = diag(exp(h_{1t}), \ldots, exp(h_{1t}))$. It is assumed that the log volatilities $h_t = (h_{1t}, \ldots, h_{nt})'$ follow a random walk process so that:

$$h_t = h_{t-1} + \zeta_t,$$

where $\zeta_t \sim N(0, \Sigma_h)$ and the initial conditions h_0 are considered as parameters to be estimated.

Two groups of time-varying parameters are considered. The first group corresponds to the $k_\beta \times 1$ vector of time-varying intercepts and coefficients of the lagged variables $\beta_t = vec((\mu_t, B_{1t}, \ldots, B_{pt})')$. The second group corresponds to the $k_\gamma \times 1$ vector of time-varying coefficients of the contemporaneous effects $\gamma_t = (\gamma_{1t}, \ldots, \gamma_{k_\gamma t})'$. Note that $k_\beta = n(np + 1)$ and $k_\gamma = n(n-1)/2$. In this way:

$$y_t = \tilde{X}_t\beta_t + W_t\gamma_t + \epsilon_t$$

where $\tilde{X}_t = I_n \otimes (1, y'_{t-1}, \ldots, y'_{t-p})$ and W_t is an $n \times k_\gamma$ lower triangular matrix with the coefficients of contemporaneous effects.

Given this, our model can be formulated as a state-space model:

$$y_t = X_t\theta_t + \epsilon_t$$

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

where $X_t = (\tilde{X}_t, W_t)$ and $\theta_t = (\beta_t', \gamma_t')'$, so that θ_t is of dimension $k_\theta = k_\beta + k_\gamma$ and the initial conditions θ_0 are treated as parameters to be estimated. Further, it is assumed that $\eta_t \sim N(0, \Sigma_\theta)$.

2.3.2. Estimation

The estimation is performed by Bayesian methods using the precision sampler of Chan and Jeliazkov (2009). So, the Gibbs sampler algorithm proceeds as follows:

(i) obtain the draws of $(\theta | y, h, \Sigma_\theta, \Sigma_h, \theta_0, h_0) \sim N(\hat{\theta}, K_\theta^{-1})$, where $\hat{\theta} = K_\theta^{-1}(X'\Sigma^{-1}y + H_\theta' S_\theta^{-1} H_\theta \alpha_\theta)$ and $K_\theta = X'\Sigma^{-1}X + H_\theta' S_\theta^{-1} H_\theta$;

(ii) using the conditional distributions of the elements of the diagonal matrix Σ_θ, obtain the draws of $(\sigma_{\theta_i}^2 | y, \theta, h, \theta_0, h_0) \sim IG(v_{\theta i} + \frac{T}{2}, S_{\theta i} + \frac{1}{2}\sum_{i=1}^{T}(\theta_{it} - \theta_{i,t-1})^2)$;

(iii) using the conditional distributions of the elements of the diagonal matrix Σ_h, obtain the draws of $(\sigma_{hj}^2 | y, \theta, h, \theta_0, h_0) \sim IG(v_{hj} + \frac{T}{2}, S_{hj} + \frac{1}{2}\sum_{i=1}^{T}(h_{it} - h_{i,t-1})^2)$;

(iv) obtain the draws of $(\theta_0 | y, h, \Sigma_\theta, \Sigma_h) \sim N(\hat{\theta}_0, K_{\theta_0}^{-1})$, where $\hat{\theta}_0 = K_{\theta_0}^{-1}(\Sigma_\theta^{-1}\theta_1 + V_\theta^{-1} a_\theta)$ and $K_{\theta_0} = \Sigma_\theta^{-1} + V_\theta^{-1}$;

(v) obtain the draws of $(h_0 | y, h, \Sigma_\theta, \Sigma_h) \sim N(\hat{h}_0, K_{h_0}^{-1})$, where $\hat{h}_0 = K_{h_0}^{-1}(\Sigma_h^{-1} h_1 + V_h^{-1} a_h)$ and $K_{h_0} = \Sigma_h^{-1} + V_h^{-1}$;

(vi) repeat steps (1)-(5) N times.

2.3.3. Model Comparison

Based on the TVP-VAR-SV model, different restricted models can be specified depending on which parameters we want to keep constant. In this way, seven models are considered: (i) TVP-VAR-SV which considers both time-varying parameters and stochastic volatility; (ii) TVP-VAR which assumes homoscedastic variances; (iii) TVP-VAR-R1-SV which assumes that intercepts and coefficients of lagged variables are constant; (iv) TVP-VAR-R2-SV which assumes that the coefficients of the contemporaneous effects are constant; (v) TVP-VAR-R3-SV which assumes that only the intercepts and the variance are time-varying; (vi) CVAR-

SV which assumes constant parameters and stochastic volatility; and (vii) CVAR which assumes constant parameters and constant volatility[3].

In accordance with Chan and Eisenstat (2018), the model comparison is performed by using the calculation of marginal likelihood and the deviance information criterion.

2.3.3.1. Marginal Likelihood

A commonly used model comparison criterion is the Bayes factor (BF), which is based on marginal likelihoods. In this way:

$$BF_{ij} = \frac{p(y|M_i)}{p(y|M_j)},$$

where $p(y|M_k) = \int p(y|\theta_k, M_k)p(\theta_k|M_k)d\theta_k$ is the marginal likelihood for the model M_k. Then, if $BF_{ij} > 1$, the model M_i is favored by the data. Chan and Eisenstat (2015) propose a marginal likelihood estimation based on a cross-entropy method which uses an importance sampling defined as:

$$\hat{p}_{IS}(y) = \frac{1}{N}\sum_{n=1}^{N}\frac{p(y|\theta_n)p(\theta_n)}{g(\theta_n)}.$$

If $g = g^* = g(\theta) = p(y|\theta)p(\theta)/p(y)$, it is obtained an estimator with variance equal to zero, such that:

$$\hat{p}_{IS}(y) = \frac{1}{N}\sum_{n=1}^{N}\frac{p(y|\theta_n)p(\theta_n)}{p(y|\theta_n)p(\theta_n)/p(y)} = p(y).$$

So, g close enough to g^* must be chosen in order to have an efficient estimator. For this purpose, it is considered a parametric family $\mathcal{F} = \{f(\theta; v)\}$ indexed by the parameter vector v within which it is found the importance density $f(\theta; v^*)$ that is the closest to g^*. This can be solved by means of:

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3 In addition, regime-switching models like those in Sims and Zha (2006) are considered. Thus, let $S_t \in \{1, \ldots, r\}$ denote the regime indicator at time t, such that r is the number of regimes, the regime-switching model (RS-VAR) is given by:

$$B_{0,S_t}y_t = \mu_{S_t} + \sum_{j=1}^{p} B_{j,S_t}y_{t-j} + \epsilon_t,$$

where $\epsilon_t \sim N(0, \Sigma_{S_t})$ and each parameter is estimated within an specific regime. Two restricted verions of this model are also considered, namely, RS-VAR-R1, which assumes that VAR coefficients are the same across regimes, and RS-VAR-R2, which assumes that the covariance matrices are the same across regimes.

$$\hat{v}_{CE}^{*} = \underset{v}{\text{argmax}} \frac{1}{L} \sum_{l=1}^{L} logf(\theta_l; v),$$

where $\theta_1, \dots, \theta_L$ are draws obtained from the posterior density. Once $\hat{v}_{CE}^{*}$ is found, a random sampling $\theta_1, \dots, \theta_N$ is generated from the density $f(\theta; \hat{v}_{CE}^{*})$ and estimate the marginal likelihood by using the importance sampling $p(y)$.

2.3.3.2. Deviance Information Criterion

The deviance information criterion (DIC) was proposed by Spiegelhalter *et al.* (2002). Unlike the Bayes factor, it has the advantage of being relatively insensitive to the prior distributions. This criterion is based on the deviance which, following Chan and Grant (2016), is defined as: $D(\theta) = -2logp(y|\theta) + 2logh(y)$, where $p(y|\theta)$ is the likelihood and $h(y)$ is a function of the data.

Given that the DIC can be conceptualized as a tradeoff between model fit and model complexity, it can be calculated as the sum of the posterior mean deviance and the effective number of parameters, so that: $DIC = \overline{D(\theta)} + p_D$, where $\overline{D(\theta)} = -2E_{\theta}(logp(y|\theta)|y) + 2logh(y)$ and $p_D = \overline{D(\theta)} - D(\hat{\theta})$. In this way: $DIC = 2\overline{D(\theta)} - D(\hat{\theta})$, where it is assumed that $h(y) = 1$. Consequently: $DIC = -4E_{\theta}(logp(y|\theta)|y) + 2logf(y|\hat{\theta})$. So, given a set of competing models, the preferred model is the one with the lowest DIC.

2.4. Empirical Results

2.4.1. Data

This study uses quarterly data for the period 1999Q1-2020Q1, which comprises 85 observations. Regarding mineral commodity prices, it is used the Metals & Minerals Price Index (2010=100) from the World Bank's database[4]. Regarding public investment and domestic output, general government's investment and GDP at constant 2007 prices from

[4] This index is calculated by assigning differentiated weights for various metals and minerals according to World Bank's estimation of the respective export values.

the database of the Central Reserve Bank of Peru (BCRP) are considered. The data for mining exports, in FOB terms, also comes from BCRP. The series of tax revenues from the mining sector and mining canon are obtained from the Peruvian National Superintendence of Customs and Tax Administration. These series are deflated using the Consumer Price Index (2009=100). Then, with the exception of the Metals & Minerals Price Index, all the series are seasonally adjusted using the Census X-13 method. All variables enter in annual growth rates into the model.

Series in log-levels and in annual growth rates are presented in the first and second column of Figure 1, respectively. It is observed that the Metals & Minerals Price Index has a remarkable increase, especially from 2003 to 2008, which is consistent with the dynamics of the commodities boom. In 2009 this index has a substantial decrease associated with the Great Recession but it shows a recovery in 2010 and 2011, mainly due to resilience of China. Then, mineral commodity prices tend to decrease with the end of the commodities boom, although there is a certain recovery since 2016. In the case of public investment, it has a noticeable decrease during the first years but then it exhibits increases, especially in response to the Great Recession. Then, it stabilizes since 2015, which corresponds to the entry into force of the Law to Strengthen Fiscal Responsibility and Transparency (Law N° 30099).

With respect to mining exports, there is a noticeable growth during the first years and also that they were substantially affected by the Great Recession and the end of the commodities super cycle. Besides, the dynamics of taxes from mining resemble that of mineral commodity prices, thus showing the dependence of this variable on external conditions. The same is the case with mining canon which, in turn, has a remarkable increase around 2002 since in that year mining canon was raised from 20% to 50% of the income tax from mining activity in accordance with Law of Canon (Law N° 27506).

In the case of GDP, it is observed a decrease in 2001, under a context of political upheaval in Peru, and an increase between 2003 and 2008, which corresponds to a period of increasing mineral commodity prices. The negative impacts of the Great Recession and the decline of mineral commodity prices are observed in 2009 and 2014, respectively.

2.4.2. Identification

Contemporaneous restrictions are used to identify the structural shocks. In order to ensure the comparability of the scales, it is considered triangular factorization which imposes a unit contemporaneous response of variables to their own shocks. Given this, the vector $y_t = [y_{1t}, y_{2t}, y_{3t}, y_{4t}, y_{5t}, y_{6t}]'$ represents the set of endogenous variables (in annual growth rates) ordered as follows: mineral commodity prices, public investment, mining exports, tax revenues from the mining sector, mining canon and domestic output.

This ordering, which is in line with Kumah and Matovu (2007), considers mineral commodity prices as the most exogenous variable since these prices are determined at the international level and Peru, as a small and open economy, does not have any relevant influence on them. Then, we have mining exports, which is introduced as a control variable, and the variables associated with fiscal revenues, namely, taxes from mining and mining canon. In turn, under this ordering, public investment can contemporaneously respond to changes in fiscal revenue variables, thus reflecting that increases in mineral commodity prices directly increase taxes from mining and mining canon, which in turn may fuel up public investment. GDP that can be contemporaneously affected by all the other variables into the system. In this way, following Fatás and Mihov (2001), Blanchard and Perotti (2002), and Perotti (2005), this ordering assumes that tax and spending decisions do not react contemporaneously to changes in real activity. This is because the model uses quarterly data and evidence on the conduct of fiscal policy shows that it takes policymakers and legislatures more than a quarter to learn about a GDP shock, decide what fiscal measures to take in response, pass them through legislation, and actually implement them.

2.4.3. Priors

The priors of the initial conditions follow a Normal distribution such that $\theta_0 \sim N(a_\theta, V_\theta)$ and $h_0 \sim N(a_h, V_h)$. In turn, it is assumed that the error variance matrices of the state equations Σ_θ and Σ_h are diagonal and that their diagonal elements are independently distributed as $\sigma^2_{\theta_i} \sim IG(v_{\theta_i}, S_{\theta_i})$ and $\sigma^2_{h_j} \sim IG(v_{h_j}, S_{h_j})$ with $i = 1, \dots, k_\theta$ and $j = 1, \dots, k_h$, respectively.

In line with Chan and Eisenstat (2018), the hyperparameters are $a_\theta = 0$, $V_\theta = 10 \times I_{k_\theta}$, $a_h = 0$ and $V_h = 10 \times I_n$. It is assumed that the prior mean of $\sigma^2_{h_j}$ is 0.1^2. In turn, the prior mean of $\sigma^2_{\theta_i}$ is 0.01^2 if it corresponds to VAR coefficients and 0.1^2 for intercepts. Regarding the degrees of freedom, small values are set, so that $v_{\theta_i} = v_{h_j} = 5$.

2.4.4. Baseline Model

In order to assess time variation in coefficients and volatility, it is performed the Kolmogorov-Smirnov test, which analyzes whether each parameter can be obtained from the same continuous distribution, and the t-test, which analyzes whether each parameter can be obtained from two distributions with the same mean. For this purpose, two subsamples are considered: from 1999Q1 (the beginning of the sample) to 2009Q2 (the middle of the sample), and from 2009Q3 to 2020Q1 (the end of the sample). The results are shown in Table 1 and in both tests there is clear evidence that the parameters vary over time. In the case of the Kolmogorov-Smirnov test, nine out of fifteen of the coefficients of contemporaneous effects change over the period 1999Q1-2009Q2 and eleven out of fifteen change over the period 2009Q3-2020Q1. As regards the t-test, fourteen out of fifteen of the coefficients of contemporaneous effects change over the period 1999Q1-2009Q2 and all of them change over the period 2009Q3-2020Q1. In turn, in both tests it is found that most of the intercepts and coefficients of the lagged variables change over time and that all parameters associated with volatility evolve over time. Alternatively, other periods for the subsamples are considered by replacing 2009Q2 with 2007Q1. The results are quite similar to the previous ones.

Table 2 shows the results of the models comparison. Regarding the log marginal likelihood, it is found that, as compared with the CVAR, the TVP-VAR-SV model is clearly preferred since the BF in favor of this model is 4.9×10^{43}. However, the best model according to this criterion is the one which assumes that only the intercepts and the variance are time-varying (TVP-VAR-R3-SV). This model has a BF of 3 and 544.6 with respect to the CVAR-SV and the TVP-VAR-R1-SV models, which rank second and third, respectively. In turn, the BF of the TVP-VAR-R3-SV as compared with the CVAR is 1.6×10^{50}. It is found that all regime-switching models have a poor performance[5]. So, for instance, the BF in favor of the TVP-VAR-R3-SV and the TVP-VAR-SV models with respect to the best model with regime-switching (RS-VAR-R2 with two regimes) are 5×10^{72} and 1.5×10^{66}, respectively. This shows that modelling a smooth and continuous change in the coefficients is more adequate than imposing an abrupt and discrete change, as in the case of regime-switching models. In turn, the models with the worst performance in terms of the log marginal likelihood are the CVAR and the TVP-VAR models. So, the best models are those which consider stochastic volatility.

Regarding the DIC, it is found that the best-performing model is the CVAR-SV. In turn, the TVP-VAR-R3-SV model, which ranked first according to the log marginal likelihood, is ranked second according to the DIC. In turn, the TVP-VAR-SV model ranks sixth under this criterion. In line with the results of the log marginal likelihood, it is found that, among the seven competing models, the TVP-VAR model has the worst performance in terms of the DIC. So, considering the results of the log marginal likelihood and the DIC, it is found that allowing for stochastic volatility is crucial in order to properly capture the dynamics of the effects of changes in mineral commodity prices on the Peruvian economy.

As regards VAR coefficients, it is considered the evolution of the parameters of the contemporaneous effects and those associated with intercepts and lagged variables. The results are available upon request. It is found that the contemporary parameters associated with the equations of mining exports growth and GDP growth exhibit a perceptible variation over time. In the case of the equations associated with taxes from mining growth, mining canon growth, and public investment growth, the contemporary parameters have little variation. In turn, regarding the intercepts and lagged variables parameters in the TVP-VAR-SV model, it is observed that most of the parameters associated with lagged variables have some variation over time, especially in the second lag. In the case of the intercepts, they have a noticeable variation, especially those associated with the equations of mining exports growth, mining canon growth, public investment growth, and GDP growth. Thus, these results show why in our case the TVP-VAR-R3-SV model (which assumes that only the intercepts and the variance are time-varying) outperforms the TVP-VAR-R1-SV model

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[5] The results of the log marginal likelihood for the regime-switching models are available upon request. The DIC is not calculated for them since the posterior distributions under these models typically have multiple modes, making the calculation of the DIC difficult (besides the fact that regime-switching models tend to exhibit bad performance).

(which assumes that intercepts and coefficients of lagged variables are constant while the contemporary parameters are time-varying).

Concerning stochastic volatility, Figure 2 presents the evolution of the standard deviation of the innovations in each equation for all models. In the case of the TVP-VAR and CVAR models there are horizontal lines since these models assume constant volatility. By contrast, in the models which consider stochastic volatility it is observed the evolution of the standard deviations over time.

Regarding the Metals & Minerals Price Index growth equation, it is observed that the standard deviation has an increasing tendency until 2009 and then it decreases until the end of the period, which can be explained by stabilization of international markets after the financial crisis and the end of the commodities super cycle.

Besides, the volatilities of mining exports and tax revenues from the mining sector follow a similar pattern since they are higher during the first years due to the new context given by the commodities super cycle and then decrease, although they exhibit some increase around 2014, which would be associated with the uncertainty due to end of the commodities boom. With respect to the volatility of mining canon, it is notoriously higher during the first years of the sample since at the beginning of the period there were changes in its determination; see Aspillaga (2006). Then, this volatility shows a decreasing tendency with some increase around 2014, as in the case of the volatility of mining exports and taxes from mining.

In turn, the volatility of public investment has a decreasing tendency during the first years, which reflects the effectiveness of the Law of Fiscal Prudence and Transparency (Law N° 27245). Then, there is some increase in the volatility of public investment around 2008-2011, which can be associated with the implementation of fiscal stimulus packages under the context of the Great Recession. After 2015, it is observed certain stabilization in this volatility, which reflects the macroeconomic stability and the impact of the implementation of the Law to Strengthen Fiscal Responsibility and Transparency (Law N° 30099), which seeks the gradual withdrawal of fiscal stimulus; see Consejo Fiscal (2016).

In the case of the standard deviation of the GDP growth equation, it is observed that its level of volatility is lower than that of the other variables. This can be explained because most of our sample period corresponds to the so-called "Great Moderation" of the Peruvian economy; see Castillo et al. (2016). In turn, GDP volatility tends to decrease but it has some increase since 2015, which can be associated with uncertainty about the Peruvian economic growth due to the end of the commodities super cycle, the deceleration of China's economic growth, the "El Niño" phenomenon, and increases in political instability.

In order to analyze impacts of shock in mineral commodity prices, the IRFs for the different models are calculated. Figure 3 presents the evolution over time of the median of the responses of the growth of public investment, mining exports, taxes from mining, mining canon, and GDP to a Metals & Minerals Price Index growth shock. In turn, the response of mining exports to shocks in mineral commodity prices is positive in all periods and exhibits a notorious variation over time, reaching a peak around 2009. Similarly, taxes from mining and mining canon have remarkably positive response to shocks in mineral commodity prices during all the study period and in both cases this response is increasingly more pronounced until reaching a peak around 2009 and then decrease. In this way, it seems that the time-varying structure of these responses is associated with the dynamics of the commodities boom, so that fiscal revenues associated with the mining sector become more susceptible to changes in mineral commodity prices to the extent that these prices have an increasing tendency. In the case of public investment, the effect is negative in the short term, which may be associated with counter-cyclical fiscal policies. Besides, the impact of shocks in mineral commodity prices on economic growth also exhibit variation over time but it is less pronounced than that of the impacts on mining exports, taxes from mining and mining canon.

On the other hand, Figure 4 shows the IRFs calculated as the median of all responses over time for all models including confidence intervals. It is observed that the response of mining exports to shocks in mineral commodity prices growth is almost proportional, which can be expected since the dynamic of mining exports is mainly determined by changes in mineral commodity prices. It can also be noted that the median responses in the different models tend to be somewhat lower in the short term than in the CVAR model, especially in the case of the TVP-VAR-R3-SV, CVAR-SV and TVP-VAR-R1-SV models.

With respect to the response of taxes from mining to shocks in mineral commodity prices growth, there is a positive response in all models. In fact, this response is clearly remarkable since an increase of 1% in the growth of mineral commodity prices generates an increase of around 1.5% in the growth of tax revenues from the mining sector. Since this impact is more than proportional, this shows that Peruvian fiscal revenues are particularly affected by fluctuations in mineral commodity prices, which clearly represents a fiscal consequence of mining dependency. It must also be noted that, the positive response of taxes from mining is statistically significant in the first five periods in all models.

As regards the response of mining canon to shocks in in mineral commodity prices growth, there is a substantial positive response in all models. In fact, in this case the response is somewhat more remarkable than that of taxes from mining since an increase of 1% in the growth of the Metals & Minerals Price Index generates an increase around 2% in the growth of mining canon. In turn, it is noted that the response of mining canon to mineral commodity prices growth shock is somewhat lower than that of the CVAR in the case of the TVP-VAR-R3-SV, the CVAR-SV, and the TVP-VAR-R1-SV models.

Given this, an interesting pattern is identified since, while the response of mining exports to shocks in mineral commodity prices growth is nearly proportional, the response of taxes from mining and mining canon are more than proportional, which shows that in the Peruvian case fiscal revenues associated with mining sector are particularly sensitive to changes in mineral prices.

With respect to public investment, it is observed that its response to mineral commodity prices growth shocks, albeit slightly negative in the short term, is not statistically significant in any period. This can be expected since public investment is mainly determined by other factor associated with discretionary government decisions. Thus, for example, Jiménez (2005) explains that in Peru public investment expenditure has been adjusted to meet the targeted deficit given that most of current expenditure is inflexible. In addition, our result is consistent with the findings of Jiménez and Tromben (2006) and Sinnott (2009) in the sense that, although fiscal revenues have positively responded to commodity price changes, this increase in revenues has not led to a matching rise in government spending due to non-expansionary fiscal decisions.

Concerning the response of economic growth to shocks in the Metals & Minerals Price Index, it is positive but minor and it is only statistically significant in some periods under the TVP-VAR-R3-SV and the CVAR-SV models, that is, the preferred models. This can be explained by the fact that the impact of shocks in mineral commodity prices growth on the whole economy may be balanced by the dynamics of other sector different from mining.

In turn, Figure 5 shows the responses of the variables to shocks in mineral commodity prices growth for specific periods, i.e., 2003Q2, 2007Q2, 2009Q1, 2013Q1, 2017Q2 and 2020Q1. These selected periods correspond respectively to the first years of the increasing tendency of mineral prices, the mid of the commodities super cycle, the Great Recession, the end of the commodities super cycle, a period of relative stability and the end of the period. Our analysis is primarily focused on analyzing the impacts of shocks in mineral commodity prices on fiscal revenue variables, i.e., taxes from mining and mining canon.

In the IRFs associated with the period 2003Q2 the magnitude of the response of mining exports, taxes from mining, mining canon and GDP to a mineral commodity prices growth shock is lower than in other periods, which is more clearly noted in the TVP-VAR-R3-SV and the CVAR-SV models. This shows that changes in mineral commodity prices have less influence on the other variables at the beginning of the commodities boom.

In the case of the IRFs associated with the period 2007Q2, the positive response of mining exports, taxes from mining, mining canon and GDP is noticeably more pronounced, so that its magnitude is the second or third largest among the different models. In this way, the impact of shocks in mineral commodity prices increases along with the increasing tendency of these prices under the commodities super cycle. This is in line with the fact that, as Ganiko and Montoro (2018) note, general government's fiscal revenues surpassed in 4.8% of GDP the projections of the Multiannual Macroeconomic Framework.

In the IRFs associated with the period 2009Q1, it is observed that the magnitude of the response of taxes from mining and mining canon is the highest in all the study period. This reveals an important fiscal consequence of Peruvian mining dependency since it is observed that fiscal variables associated with the mining sector become increasingly more sensitive to changes in mineral commodity prices in line with the increasing tendency of these prices and, when there is an abrupt decrease of the prices due to events like the Great Recession, taxes from mining and mining canon are strongly and negatively affected. This is in line with the findings of Ossowski and Halland (2016), who note that in several resource-rich countries fiscal vulnerability to resource shocks increased during the resource price boom.

Regarding the IRFs associated with the period 2013Q1, it is observed that in most of cases the magnitude of the responses of mining exports, taxes from mining, mining canon and GDP is similar to the magnitude of the responses of the IRFs associated with the period 2007Q2. This shows that the influence of shocks in mineral commodity prices, after reaching a peak around the Great Recession, returns to a level similar to that at the mid of the commodities super cycle. In this way, as Consejo Fiscal (2017) notes, with the end of the commodities super cycle, the lower tax collection is associated with reductions in the value of commodity exports.

Concerning the IRFs associated with the period 2017Q2, it is noted that the response of taxes from mining and mining canon is even less pronounced than in the period 2013Q1 in most of cases, which is in line with the stabilization of mineral commodity prices after the commodities super cycle; see Consejo Fiscal (2018). The same is the case in the IRFs associated with the period 2020Q1. In fact, the magnitude of the responses of taxes from mining and mining canon is similar to that at the beginning of the commodities boom or even somewhat less pronounced, as in the case of the TVP-VAR-R1-SV and the TVP-VAR-SV models.

Figure 6 shows the time evolution of the forecast error variance decomposition (FEVD) of taxes from mining growth and mining canon growth at different horizons considering shocks in the six variables for the different models. This represents the dynamics of the different sources of uncertainty of the evolution of the variables at the short (horizon 2), medium (horizon 8) and long term (horizon 20).

In the case of the FEVD of taxes from mining, it is found that it is mainly explained by its own shocks in the short term in all models. This is consistent with the fact that in Peru there is certain legal uncertainty associated with changes in tax legislation that may affect fiscal revenues from the mining sector. In turn, it is observed that the importance of shocks in the Metals & Minerals Price Index growth initially increases in line with the increase of mineral commodity prices. This can be expected since, to the extent that mineral commodity prices increase, it is generated an increasing uncertainty about how long this positive tendency will last and how it can affect fiscal revenues. Then, it is observed that the importance of shocks in mineral commodity prices reaches a peak around 2009 so that shocks in the Metals & Minerals Price Index explain around 40% of fluctuations in taxes from mining in the different models. In the case of the CVAR-SV model this importance is more noticeable since those shocks explain around 50% of the fluctuations. This shows that shocks in mineral commodity prices constitute a relevant source of uncertainty for tax revenues from mining, which is in line with the findings of Cordano and Balistreri (2010). In addition, it is consistent with the fact that the Great Recession involved a great uncertainty about international economic conditions, which is reflected by means of the Metals & Minerals Price Index since it is the external variable in our system.

After the Great Recession, the importance of shocks in the Metals & Minerals Price Index tends to decrease until reaching an influence of between 10 and 20% at the end of the period. This relatively low level implies that, in a normal situation, shocks in mineral commodity prices do not represent an important source of uncertainty for fiscal revenues from the mining sector since the agents already take into account the volatile character of mineral prices as a constituent part of the fluctuations of taxes from mining. However, when there are special episodes like the remarkable increasing tendency of mineral commodity prices during the resources boom, this introduces substantially more uncertainty about how fiscal revenues could be affected. In turn, the fact that shocks in mining exports have a minor importance in explaining fluctuations in tax revenues shows that these fluctuations are mainly due to a price-effect; see Mendoza and De Echave (2016). Besides, it must be noted that in the CVAR model the importance of the different shocks remains the same over time, which contrast with our methodology that allows us to see more clearly how the importance of the shocks evolve over time in line with the dynamics of the commodities super cycle.

Concerning the FEVD of mining canon, it is explained to a great extent by its own shocks, especially during the first half of the period and that this is more notorious in the TVP-VAR-R3-SV, CVAR-SV, TVP-VAR-R2-SV and TVP-VAR models. This shows that fluctuations in mining canon constitute an important source of uncertainty for themselves, thus reflecting the remarkable volatility of this variable. This finding is important in terms of the prospects for development of Peruvian regions because, in line with Ahmad and García-Escribano (2006), it implies that the uncertainty about mining canon will translate into uncertainty about the availability of funds that local governments may use to finance public investment. Besides, it is observed that shocks in taxes from mining represent a relevant source of uncertainty for mining canon, with an increasing importance towards the end of the period. This is because shocks in taxes from mining are associated to changes in the fiscal framework which affect the collection of mining canon.

Regarding the importance of mineral commodity prices in explaining fluctuations in the mining canon, it is found that shocks in the Metals & Minerals Price Index have an increasing importance during the period of increasing mineral prices. Then, they reach a peak around the Great Recession, which shows that the economic uncertainty about the conditions of international markets also poses a remarkable uncertainty about mining canon. In this way, shocks in the Metals & Minerals Price Index explain around 50% of fluctuations in mining canon in the CVAR-SV and around 40% in the TVP-VAR-R3-SV, the TVP-VAR-R1-SV, and the TVP-VAR-R2-SV models. Furthermore, it is noted that the importance of shocks in mineral commodity prices in explaining fluctuations in mining canon tends to decrease during the second half of the period, thus coinciding with the end of the commodities boom. It is again observed that in the CVAR model the importance of the shocks is the same over time.

Figure 7 presents the historical decomposition (HD) of taxes from mining growth and mining canon growth for the different models. In the case of taxes from mining growth, there is some decrease at the beginning of the period, which is mainly associated with the deficient performance of mining exports before the commodities boom. Then, since 2003 there is a noticeable increase in taxes from mining, which is substantially explained by shocks in mineral commodity prices, thus reflecting the dependency of Peruvian fiscal revenues on external factors. The effect of the Great Recession is clearly noted since there is a very substantial decrease of taxes from mining around 2009. The fact that virtually all this decrease is explained by shocks in the mineral commodity prices in all models clearly shows the consequences of mining dependency since the decline in these prices generates a great reduction in fiscal revenues.

This negative impact of shocks in mineral commodity prices is also observed during the decrease of mineral prices after the end of the commodities boom along with negative impacts associated with the decrease of mining exports in that period since reductions in the value of mining exports affect tax collection; see Consejo Fiscal (2019). In turn, it must be noted that there is a perceptible role of shocks in tax revenues from mining in explaining its own fluctuations. For instance, in 2014 there is a clearly noticeable positive impact of shocks in taxes from mining, which is basically due to the extraordinary fiscal revenues from the sale of the mining company Las Bambas; see Mendoza and De Echave (2016). In turn, in 2015 and also in 2019 there is a perceptible negative impact of shocks in taxes from mining, which would be associated with reductions in the income tax rate. The stated aim of that measure was that the companies, having less tax burden, would have more funds to invest in economic recovery given the context of the deceleration of China's economic growth; see Tian (2019).

On the other hand, regarding the dynamics of mining canon growth, it is observed that during the period 1999-2003 it is mainly explained by its own shocks, which is associated with changes in its determination since mining canon was 20% of the income tax from the holders of the mining activity but from June 2002 this percentage was raised to 50%. So, after this change there is a remarkable increase in mining canon in 2002 and 2003. Then, during the period of increasing mineral commodity prices between 2004 and 2008, the increase in mining canon is perceptibly influenced by shocks in these prices. In the same way, when there is a substantial reduction in mineral prices during the Great Recession, they have a strong negative impact on mining canon since virtually all the fall around 2009 is explained by shocks in mineral commodity prices.

There is also a perceptible decrease in mining canon during 2014 and 2015, which corresponds to the Humala's administration and is consistent with the fact that, although Humala initially sought to promote some fiscal progressivity, his efforts were not successful and tax exemptions were given to mining companies in order to avoid economic slowdown; see Consejo Fiscal (2018). So, for instance, the Law N° 29230, published on November 16, 2014, authorized national government to use the procedure of Obras por Impuestos (Public Works in Exchange for Taxes), by which mining companies may obtain tax deductions if they execute public works, so that funds for mining canon available for regional and local governments are reduced. In turn, it is also noted that shocks in mining exports have a perceptible role in explaining the reductions of mining canon between 2013 and 2017, which shows that the decline in mining exports negatively affected this source of fiscal revenues.

In addition, it is analyzed how changes in the growth rate of taxes from mining and mining canon are due to shocks in the variables of the model in different proportions during some periods. These calculations are based on the HD of the preferred model, namely, TVP-VAR-R3-SV, and the results are available upon request. In order to better illustrate the evolution of the influence of mineral commodity prices, it is considered the period 2005-2006, in which there was an increase of mineral commodity prices in the context of the commodities boom, and the period 2016-2017, in which there was some increase of mineral commodity prices, but after the commodities boom.

In the case of taxes from mining, the growth rate had an increase from 51.3% in 2005 to 88.0% in 2006, which was mainly due to shocks in mineral commodity prices which explained around 83% of that increase. In turn, the growth of taxes from mining an increase from -3.5% in 2016 to 44.9% in 2017, which was mainly due to shocks in mineral commodity prices which explained around 62% of that increase. On the other hand, in the case of mining canon, the growth rate an increase from 78.2% in 2005 to 118.8% in 2006, which was mainly due to shocks in mineral commodity prices which explained around 73% of that increase. Besides, the growth rate of mining canon had an increase from -29.9% in 2016 to 75.4% in 2017, which was mainly due to shocks in mining canon which explained around 46% of that increase (shocks in mineral commodity prices explained around 35%). This clearly confirms our finding that the impact of shock in mineral commodity prices is more relevant during the resources boom and decreases in the post boom phase.

2.4.5. Robustness Analysis

Our first and main robustness test consists in using an alternative measure of mineral commodity prices which is specifically constructed for Peru. Thus, it is used a Minerals Price Index based on the specific information from the Central Reserve Bank of Peru's database. This index considers the prices of a basket of minerals comprised of cooper, tin, iron, gold, silver, lead, zinc, and molybdenum giving different weights in terms of the respective export volumes each year. Then, the Fisher Index (2007=100) is calculated by taking the geometric average of the respective Laspeyres and Paasche Indexes. So, this index is more adequate since it overcomes the problem of overestimation associated with Laspeyres method and the problem of underestimation associated with Paasche's method; see Shrestha et al. (2017).

Table 3 (panel A) shows the models selection using this alternative index. As in the baseline case, the results show that considering stochastic volatility is essential in order to correctly capture the dynamics of the system and that the preferred models are TVP-VAR-R3-SV and CVAR-SV. Figure 8 presents the evolution over time of the median of the responses of the growth of mining exports, taxes from mining, mining canon, public investment and GDP to shocks in our Minerals Price Index. The results are similar to those in the baseline case, but the responses of taxes from mining and mining canon tend to be somewhat more pronounced since an increase of 1% in the growth of our index generates an increase of around 2% and 3% in the growth of taxes from mining and mining canon, respectively. In turn, as shown in Figure 9, the pattern of time-variation of the responses is again in line with the dynamics of the commodities boom reaching a peak around the Great Recession. This pattern is found in the different models but it is more noticeable in the TVP-VAR-R3-SV and CVAR-SV. Nevertheless, in the TVP-VAR-R1-SV model the responses of taxes from mining in the IRFs associated with the periods 2009Q2 and 2013Q1 are similar in magnitude. Besides, the patterns of variance decomposition in Figure 10 resemble those of the baseline case, with the difference that with our Minerals Price Index the importance of shocks in mineral commodity prices in explaining fluctuations in the other variables becomes more noticeable, reaching a peak of around 50% and 60% during the Great Recession in the TVP-VAR-R3-SV and CVAR-SV models, respectively. Similarly, in Figure 11 it is observed that shocks in mineral commodity prices become more important in explaining the historical decomposition of taxes from mining and mining canon.

Additionally, other robustness tests are considered, the results of which are available upon request: (i) more diffuse priors, so that the prior mean of the variance of errors is 0.1^2 if it corresponds to VAR coefficients and 1^2 for intercepts, and (ii) an alternative ordering of the variables (i.e., mineral commodity prices, mining exports, public investment, taxes from mining, mining canon, and domestic output), so that public investment does not contemporaneously respond to shocks in taxes from mining, mining canon and domestic output, thus reflecting that, in the Peruvian case, public budget is determined with anticipation in order to guarantee fiscal sustainability in spite of volatility in public revenues; see Consejo Fiscal (2018).

Regarding (i), the ranking of the models is like that of the baseline case, as can be seen in Table 3 (panel B). Thus, the TVP-VAR-R3-SV and the CVAR-SV models are the best performing according to the log-marginal likelihood and the DIC, respectively. With respect to the medians of all responses over time, the results are similar to those in the baseline case. However, the impact of mineral commodity prices on GDP is less noticeable in most of models since an increase of 1% in the growth of mineral commodity prices generates only an increase of around 0.1% in GDP growth. In turn, some of the confidence intervals become narrower. Besides, it is again noted that the responses vary over time in line with the dynamics of the commodities boom although in the preferred model, i.e., TVP-VAR-R3-SV, there is somewhat less time-variation in the responses as compared with the baseline specification, especially in the case of the responses of mining exports, taxes from mining, and GDP to shocks in mineral commodity prices. As regards the variance decomposition, the results are qualitatively and quantitatively similar to those in the baseline case. Nevertheless, the importance of shocks in mineral commodity prices has some decrease in the preferred model since they explain around 35% of fluctuations in taxes from mining and mining canon. Besides, the results of the historical decomposition resemble those of the baseline model.

Concerning (ii), it is found that, as shown in Table 3 (panel C), the ranking of the models corresponds to that of the baseline case, although the TVP-VAR-SV model slightly outperforms the TVP-VAR-R2-SV model according to the marginal likelihood. The patterns observed for the IRFs in the baseline case remain, both in the median of all responses over time and the responses for specific period, so that in the period 2009Q1 the effects of shocks in mineral commodity prices reach a peak by generating an increase of around 2% and 3% in the growth of taxes from mining and mining canon. It is again found that the response of public investment to shocks in mineral commodity prices is insignificant. As regards the variance decomposition, the results resemble those of the baseline case. However, under this alternative ordering the importance of shocks in public investment tends to increase towards the second half of the period by explaining around 20% of fluctuations in taxes from mining and mining canon in the TVP-VAR-R3-SV, CVAR-SV and TVP-VAR-R2-SV models. Regarding the historical decomposition, the results are qualitatively and quantitatively similar to those in the baseline case.

2.5. Conclusions

The issue of the impact of commodity prices on fiscal variables and economic performance has attracted considerable attention in academic research. This paper shows evidence about the evolution of the effects of mineral commodity prices on fiscal variables in Peru. The analysis is conducted by estimating a TVP-VAR-SV model, which is compared with alternative specifications by means of the marginal likelihood and the DIC. The results show that considering stochastic volatility is essential in order to correctly capture the dynamics of the system. The preferred model is the one in which only the intercepts and the variance are time-varying (TVP-VAR-R3-SV).

The IRFs show that the impact of mineral commodity prices on fiscal fluctuations is more than proportional since an increase of 1% in the growth of mineral commodity prices generates increases of around 1.5% and 2.5% in the growth of taxes from mining and mining canon. In addition, it is found that the response of taxes from mining and mining canon to shocks in mineral commodity prices is increasingly more pronounced until reaching a peak around 2009 and then decrease, which is in line with the dynamics of the commodities boom. Regarding the FEVD, the importance of shocks in mineral commodity prices growth in explaining the growth of taxes from mining and mining canon increases in line with the increase of those prices until reaching a peak during the Great Recession, where shocks in mineral commodity prices explain between 40% and 50% of fluctuations in taxes from mining and mining canon, and then decreases with the end of the commodities super cycle. Concerning the HD, it is found that the dynamics of taxes from mining and mining canon is driven by shocks in mineral commodity prices to a great extent, especially in 2009, where the decline in those prices generated a great reduction in fiscal revenues. It must be noted that mining canon is also explained to a great extent by its own shocks in the first years, which is associated with legal changes regarding its determination. These results are robust to an alternative measure of mineral commodities prices, different priors, and another ordering of the variables.

In terms of recommendations, since our results show the importance of considering a time-varying structure for correctly modelling the impacts of shocks in mineral commodity prices, policy-makers should integrate time-varying parameters and, more importantly, stochastic volatility in their forecast equations of fiscal variables. In this way, they may incorporate the particularities of the economic context in order to better measure the magnitude of shocks in mineral commodity prices and adjust the fiscal framework according to it. They also could consider alternative identification schemes. On the other hand, since there is a remarkable vulnerability of taxes from mining and mining canon to shocks in mineral commodity prices so that they have a very remarkable fall when these prices decrease, Peruvian authorities should seek alternatives to shelter the economy from fluctuations in mineral commodity prices. Thus, in line with the recommendations of Consejo Fiscal (2017), they should promote productive diversification by facilitating and supporting the expansion of sectors different from mining in order to bolster the resilience of the economy to external shocks, especially those in mineral commodity prices.

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Table 1. Tests for Time Variation in Coefficients and Volatility

Kolmogorov-Smirnov test			
$\mathbf{B}_0$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
9/15	11/15	9/15	11/15
$\mathbf{B}_i$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
46/78	52/78	48/78	53/78
$\mathbf{h}$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
6/6	6/6	6/6	6/6
t-test			
$\mathbf{B}_0$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
14/15	15/15	15/15	15/15
$\mathbf{B}_i$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
46/78	49/78	44/78	47/78
$\mathbf{h}$			
1999Q1-2009Q2	2009Q2-2020Q1	1999Q1-2007Q1	2007Q1-2020Q1
6/6	6/6	6/6	5/6

$\mathbf{B}_0$ represents the coefficients of contemporaneous relationships, $\mathbf{B}_i$ represents the coefficients associated to intercepts and lagged variables, and $\mathbf{h}$ represents the coefficients associated to volatility.

Table 2. Models Selection

Model	log-ML	s.e.	Rank	DIC	s.e.	Rank	p_D	s.e.
TVP-VAR-SV	-2189.5	0.24	4	3930.5	1.85	6	88.4	0.84
TVP-VAR	-2385.2	0.34	7	3980.6	2.52	7	84.4	0.77
TVP-VAR-R1-SV	-2180.8	0.28	3	3878.6	0.55	3	101.6	0.18
TVP-VAR-R2-SV	-2189.7	0.38	5	3912.5	2.20	5	90.5	0.79
TVP-VAR-R3-SV	**-2174.5**	**0.34**	**1**	**3858.2**	**0.81**	**2**	**108.5**	**0.40**
CVAR-SV	**-2175.6**	**0.08**	**2**	**3852.3**	**0.16**	**1**	**107.9**	**0.13**
CVAR	-2290.1	0.03	6	3879.5	0.25	4	93.6	0.12

For the calculations in each model a total of 100,000 posterior draws are obtained from 10 parallel chains after a burn-in of 1,000 in every chain, and keep every 10th draw for 10,000 posterior draws.

Table 3. Models Selection for Robustness Analysis

Model	log-ML	s.e.	Rank	DIC	s.e.	Rank	p_D	s.e.
(A) Alternative Measure of Mineral Commodity Prices								
TVP-VAR-SV	-2160.3	0.30	5	3878.9	1.17	6	88.0	0.63
TVP-VAR	-2353.4	0.37	7	3923.5	2.47	7	84.6	0.64
TVP-VAR-R1-SV	-2150.7	0.16	3	3825.8	0.87	3	102.1	0.23
TVP-VAR-R2-SV	-2157.7	0.21	4	3856.5	1.43	5	90.0	0.54
TVP-VAR-R3-SV	**-2144.8**	**0.30**	**1**	**3809.3**	**0.74**	**2**	**108.9**	**0.35**
CVAR-SV	**-2145.4**	**0.04**	**2**	**3799.5**	**0.40**	**1**	**107.4**	**0.20**
CVAR	-2257.3	0.02	6	3827.4	0.46	4	93.8	0.22
(B) Alternative Specification of Priors								
TVP-VAR-SV	-2190.6	0.34	5	3939.1	1.73	6	87.1	0.32
TVP-VAR	-2385.2	0.35	7	3978.6	1.70	7	83.3	0.59
TVP-VAR-R1-SV	-2180.8	0.30	3	3878.5	0.63	3	102.1	0.32
TVP-VAR-R2-SV	-2186.5	0.21	4	3912.3	1.59	5	88.5	0.67
TVP-VAR-R3-SV	**-2175.0**	**0.41**	**1**	**3864.3**	**0.67**	**2**	**106.3**	**0.35**
CVAR-SV	**-2175.8**	**0.03**	**2**	**3851.7**	**0.33**	**1**	**107.5**	**0.15**
CVAR	-2290.1	0.01	6	3879.8	0.30	4	93.7	0.15
(C) Alternative Ordering of the Variables								
TVP-VAR-SV	-2187.3	0.26	4	3930.8	2.09	6	88.4	0.98
TVP-VAR	-2381.9	0.42	7	3980.7	1.45	7	85.1	0.59
TVP-VAR-R1-SV	-2178.6	0.22	3	3878.0	0.64	3	101.8	0.31
TVP-VAR-R2-SV	-2187.6	0.30	5	3913.3	1.80	5	90.6	0.79
TVP-VAR-R3-SV	**-2172.2**	**0.45**	**1**	**3863.1**	**0.99**	**2**	**109.5**	**0.34**
CVAR-SV	**-2173.0**	**0.06**	**2**	**3852.5**	**0.36**	**1**	**107.4**	**0.13**
CVAR	-2287.0	0.02	6	3879.8	0.30	4	93.7	0.16

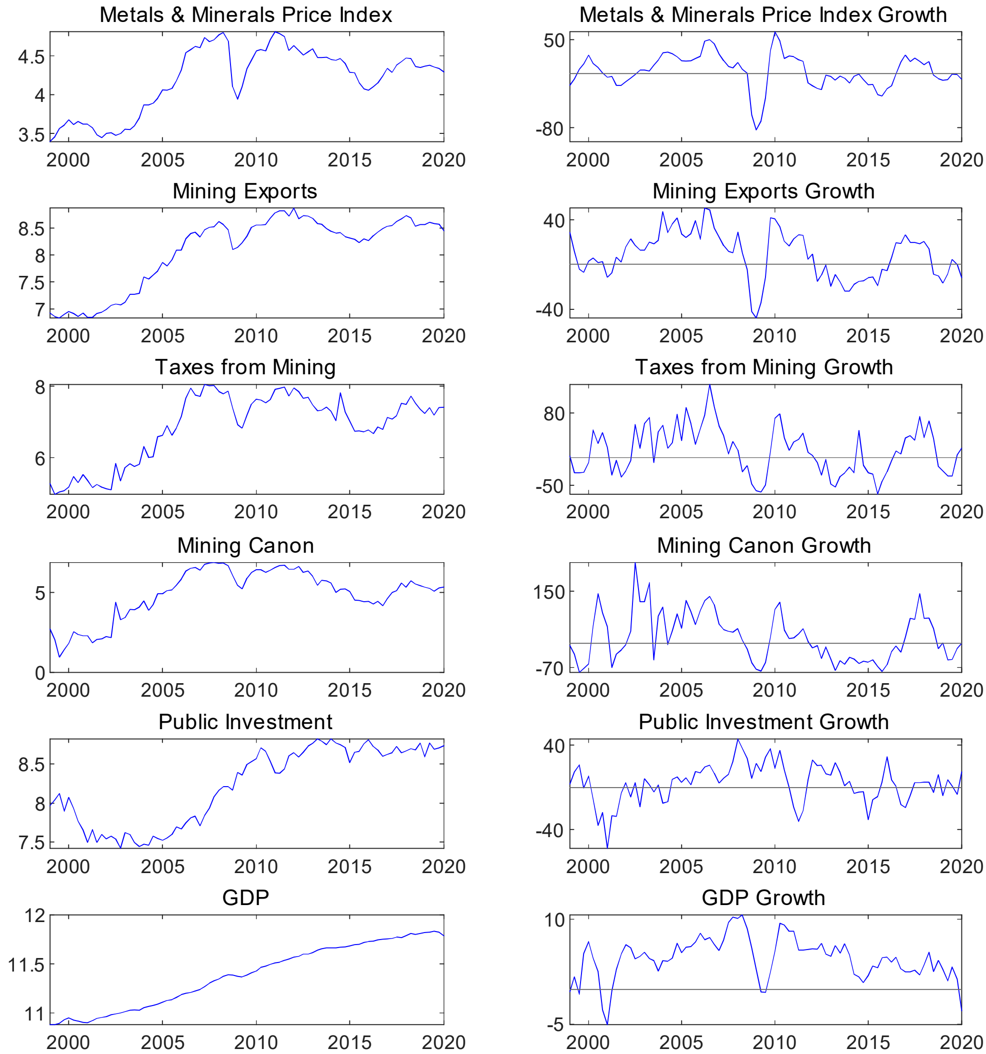

Figure 1. Variables in Log Levels (First Column) and Annual Growth Rates (Second Column)

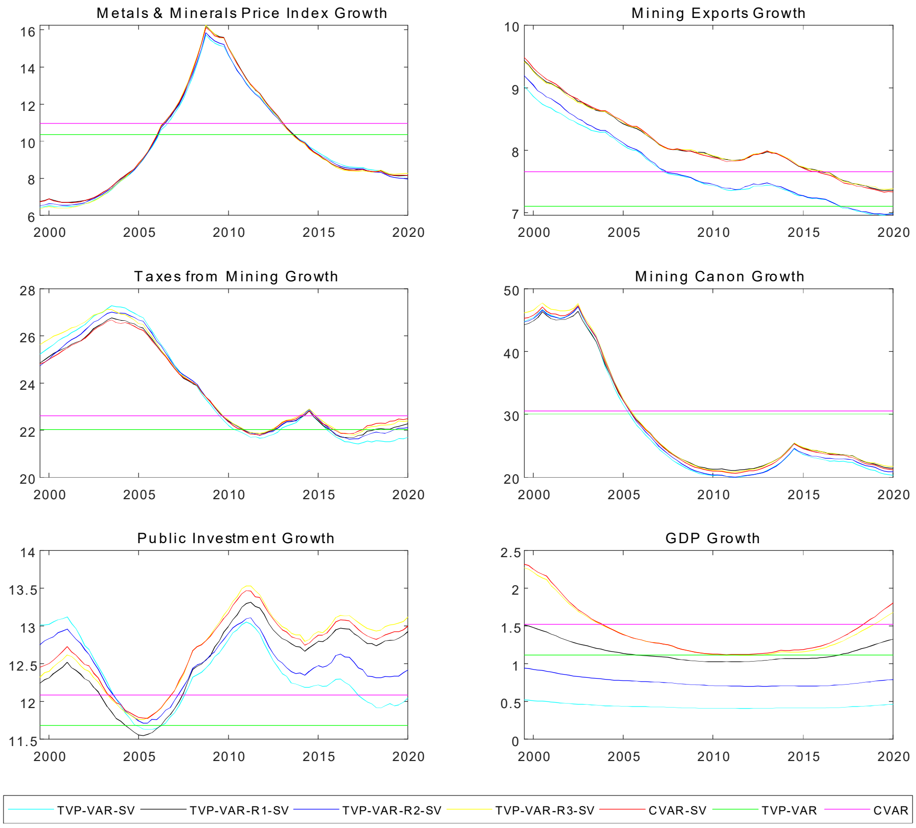

Figure 2. Evolution of the Standard Deviation of the Innovations in Each Equation, Median Values.

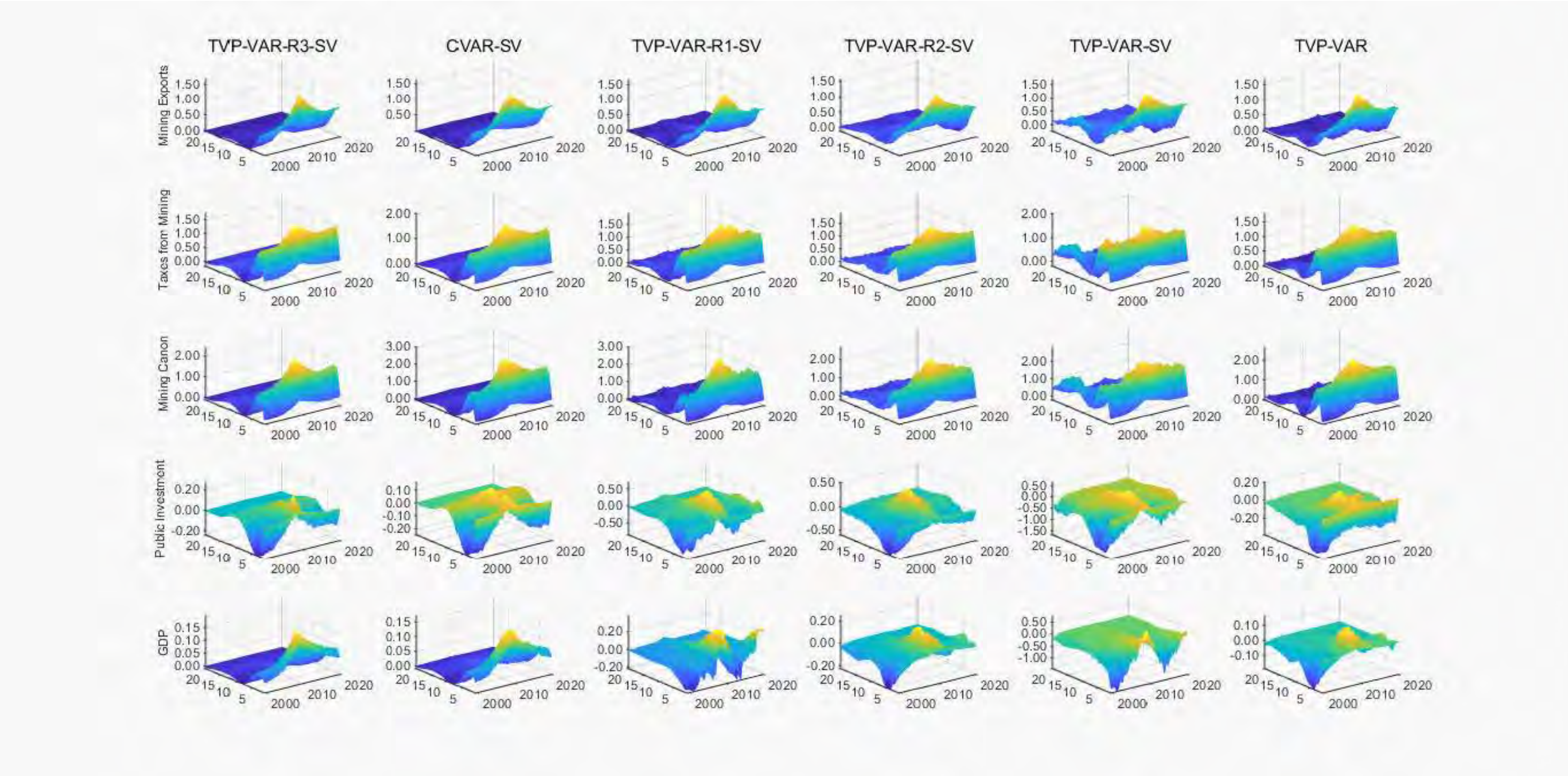

Figure 3. Time-Varying IRFs to a Metals & Minerals Price Index Growth Shock. The shock is normalized to increase the Metals & Minerals Price Index Growth by 1% at each point in the sample period.

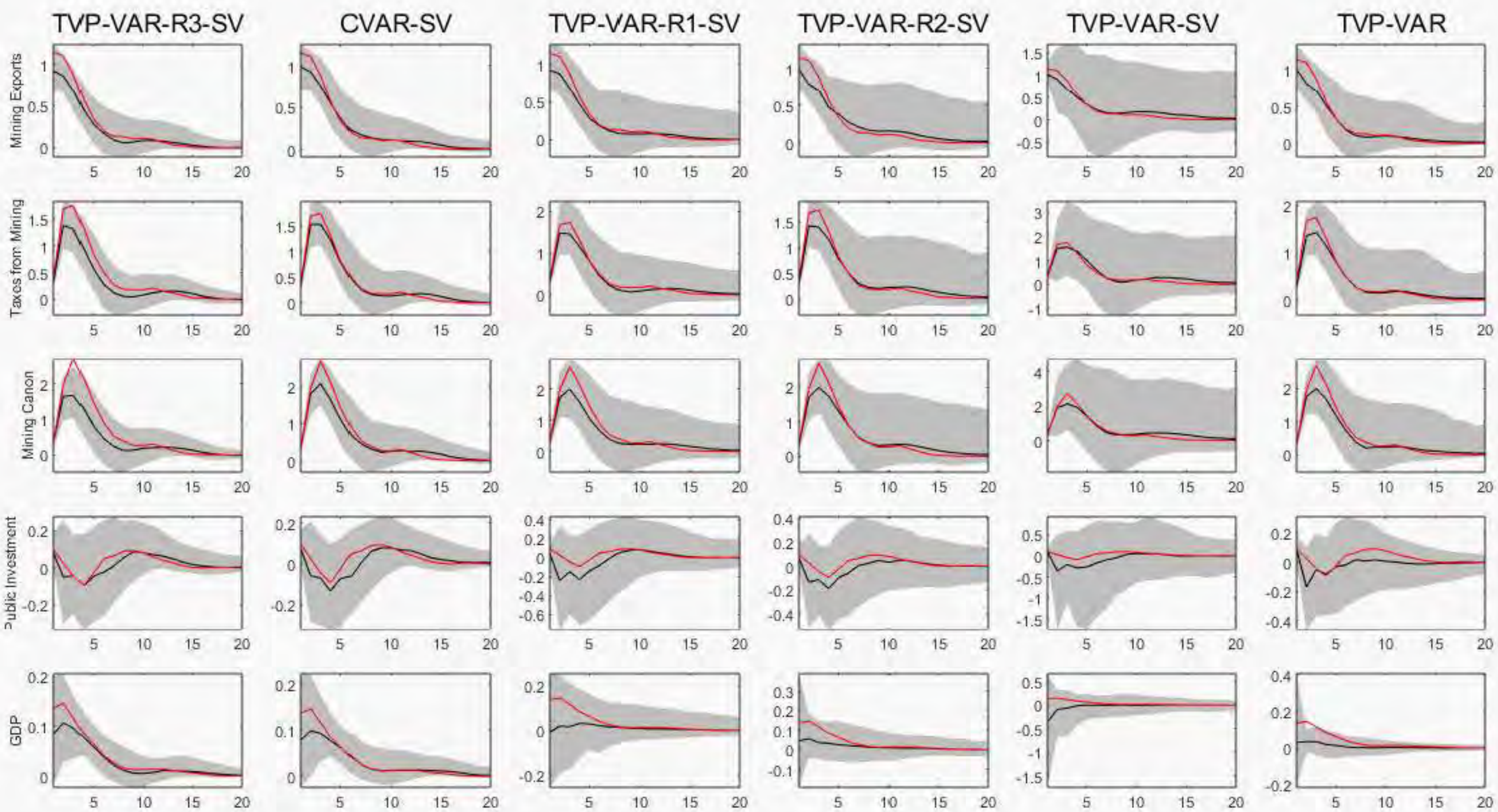

Figure 4. Median of the IRFs to a Metals & Minerals Price Index Growth Shock. The black line represents the respective model and the shaded area its 68% error band; as a benchmark, the red line represents the CVAR model.

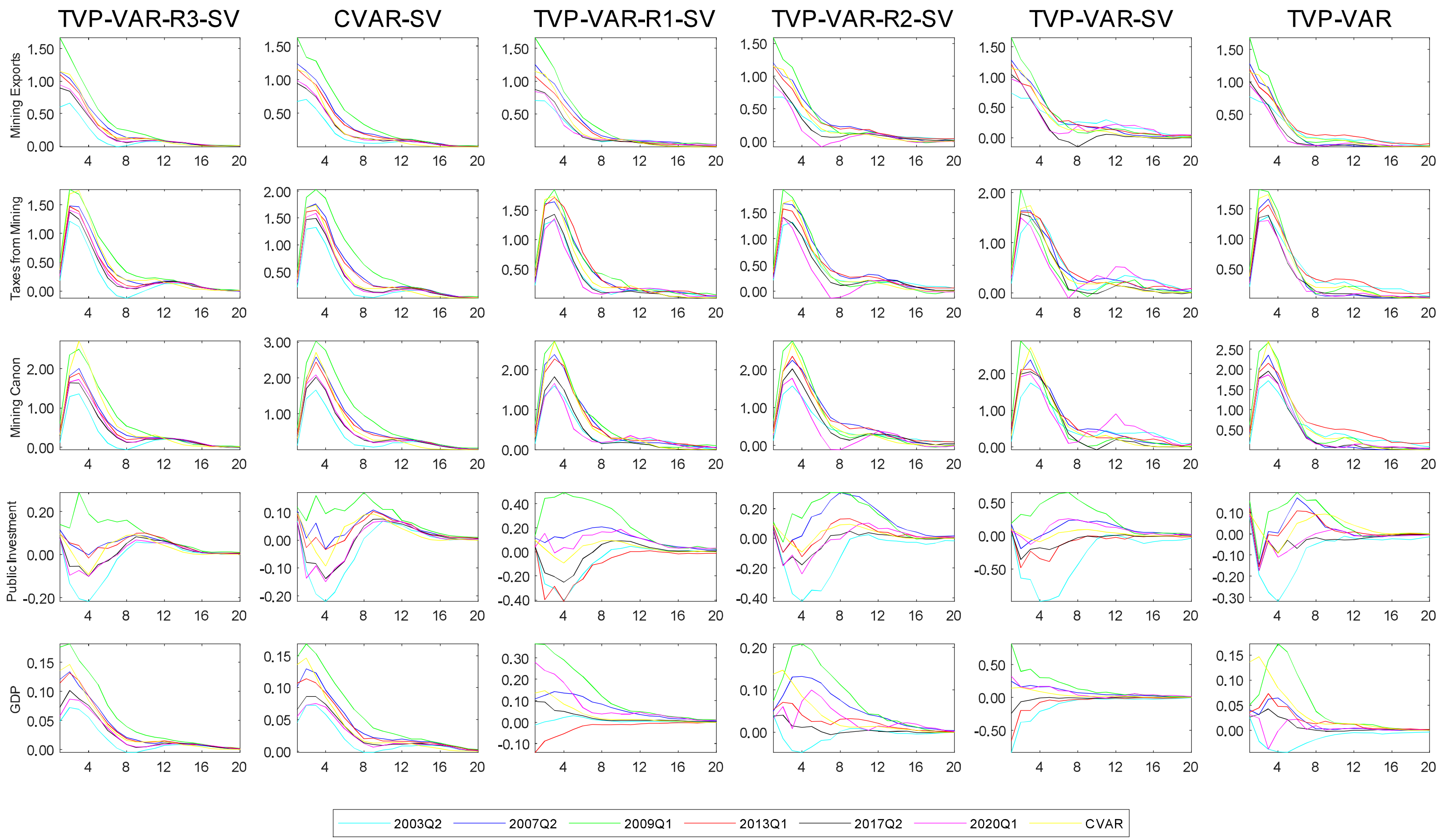

Figure 5. IRFs at Selected Time Periods to a Metals & Minerals Price Index Growth Shock.

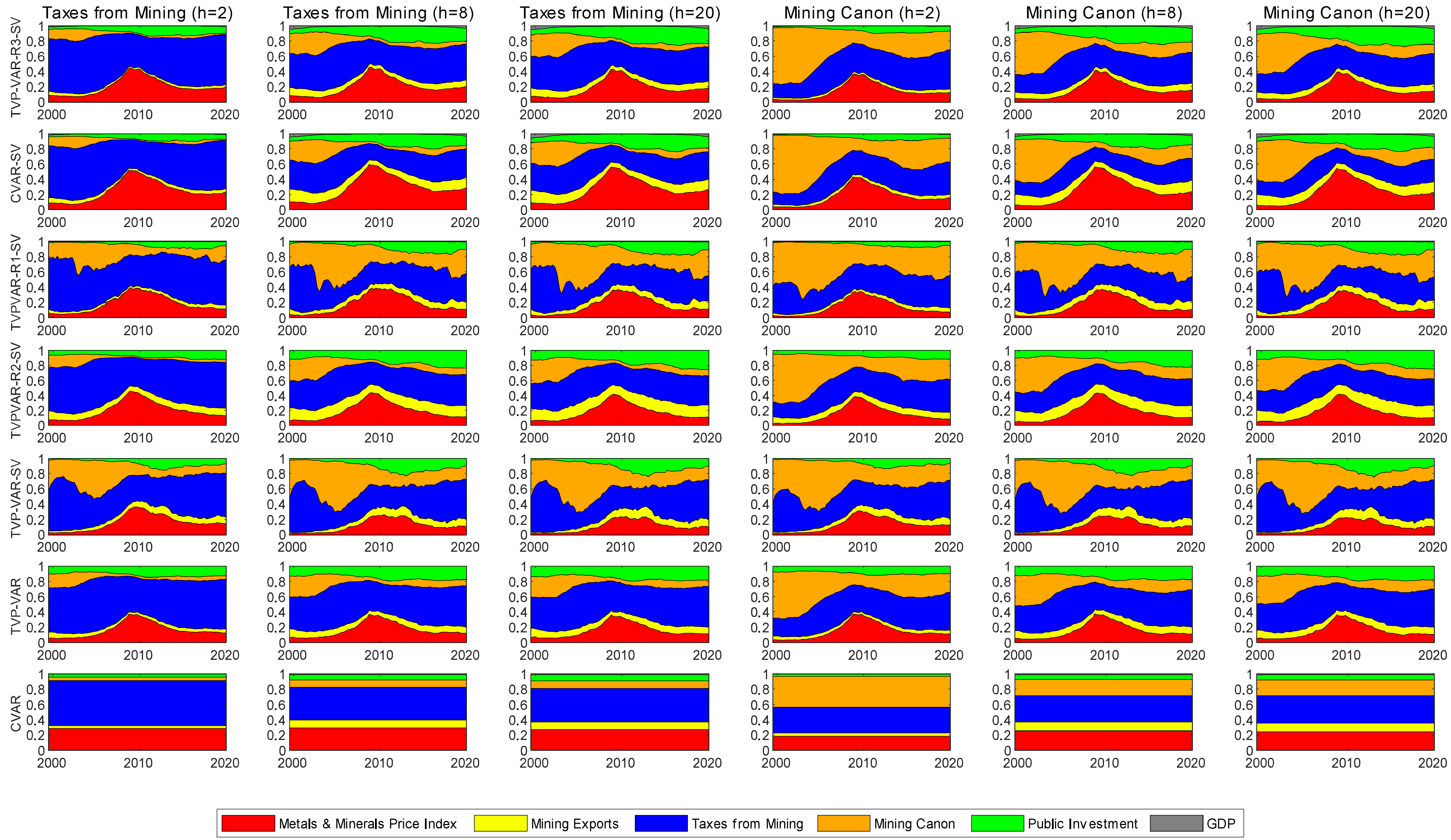

Figure 6. Time Evolution of the FEVD of Taxes from Mining Growth and Mining Canon Growth for All Models at Different Horizons.

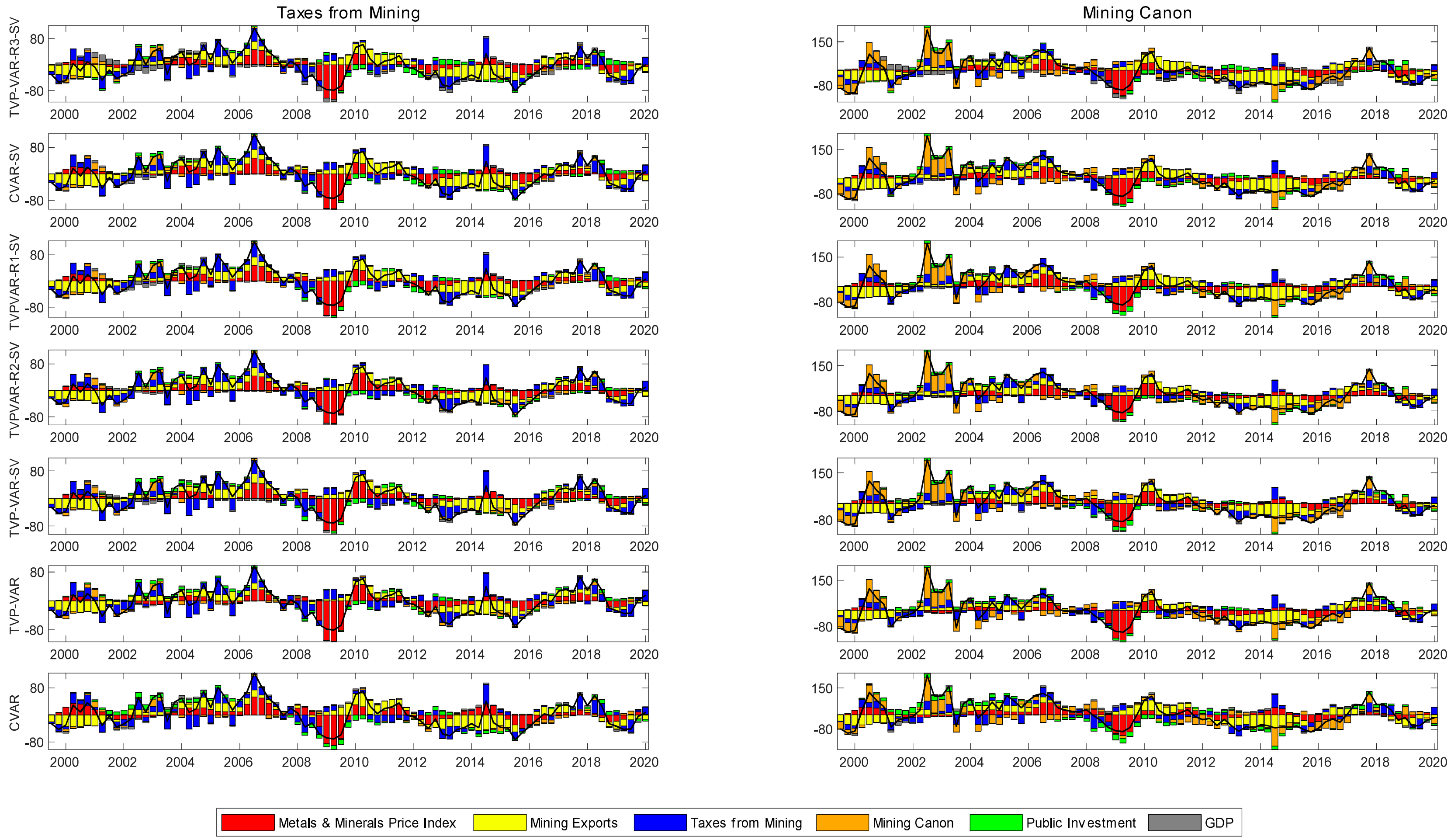

Figure 7. Historical Decomposition of Taxes from Mining Growth and Mining Canon Growth for All Models.

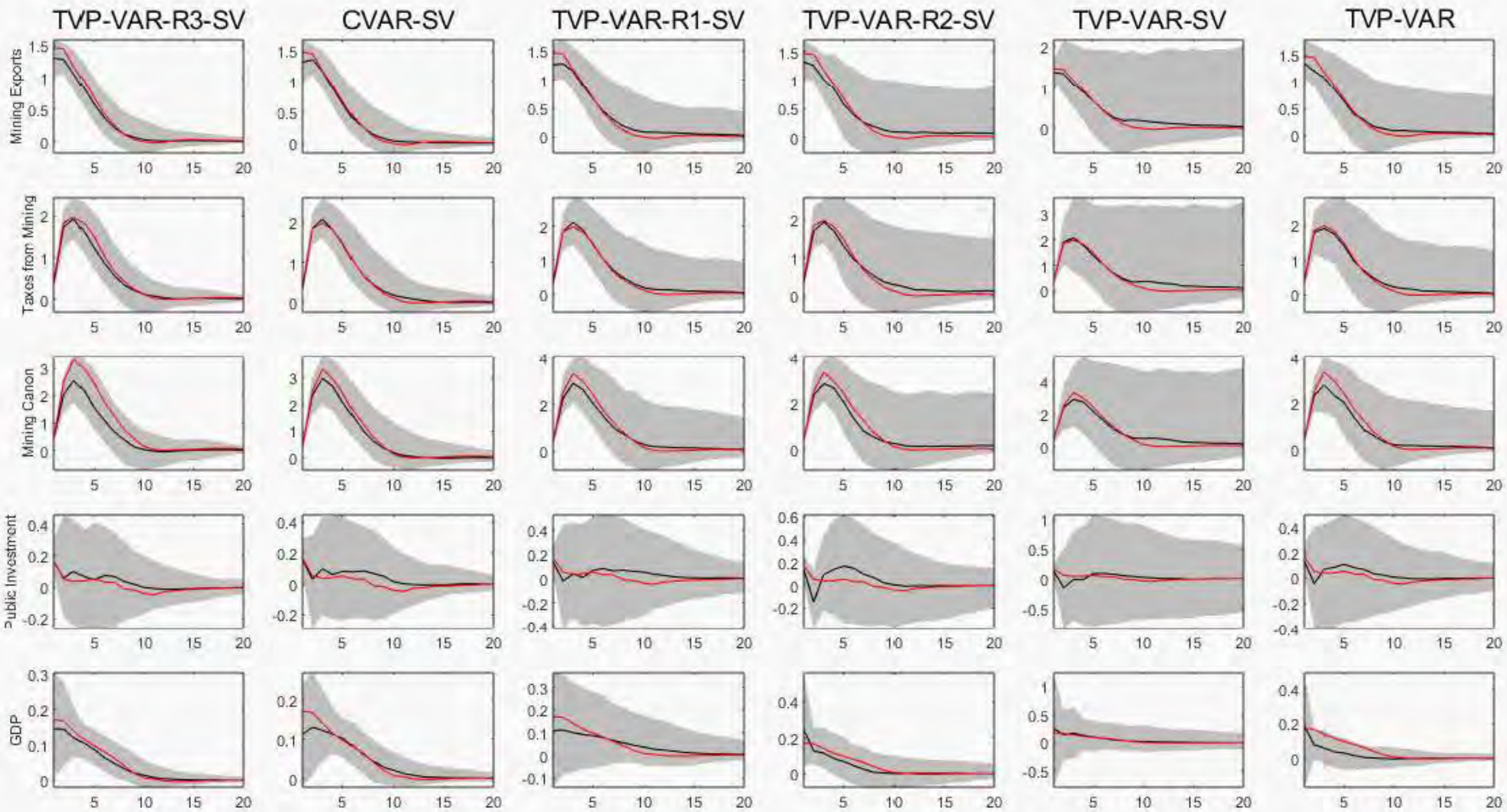

Figure 8. Median of the IRFs under Alternative Measure of Mineral Commodity Prices. The black line represents the respective model and the shaded area its 68% error band; as a benchmark, the red line represents the CVAR model.

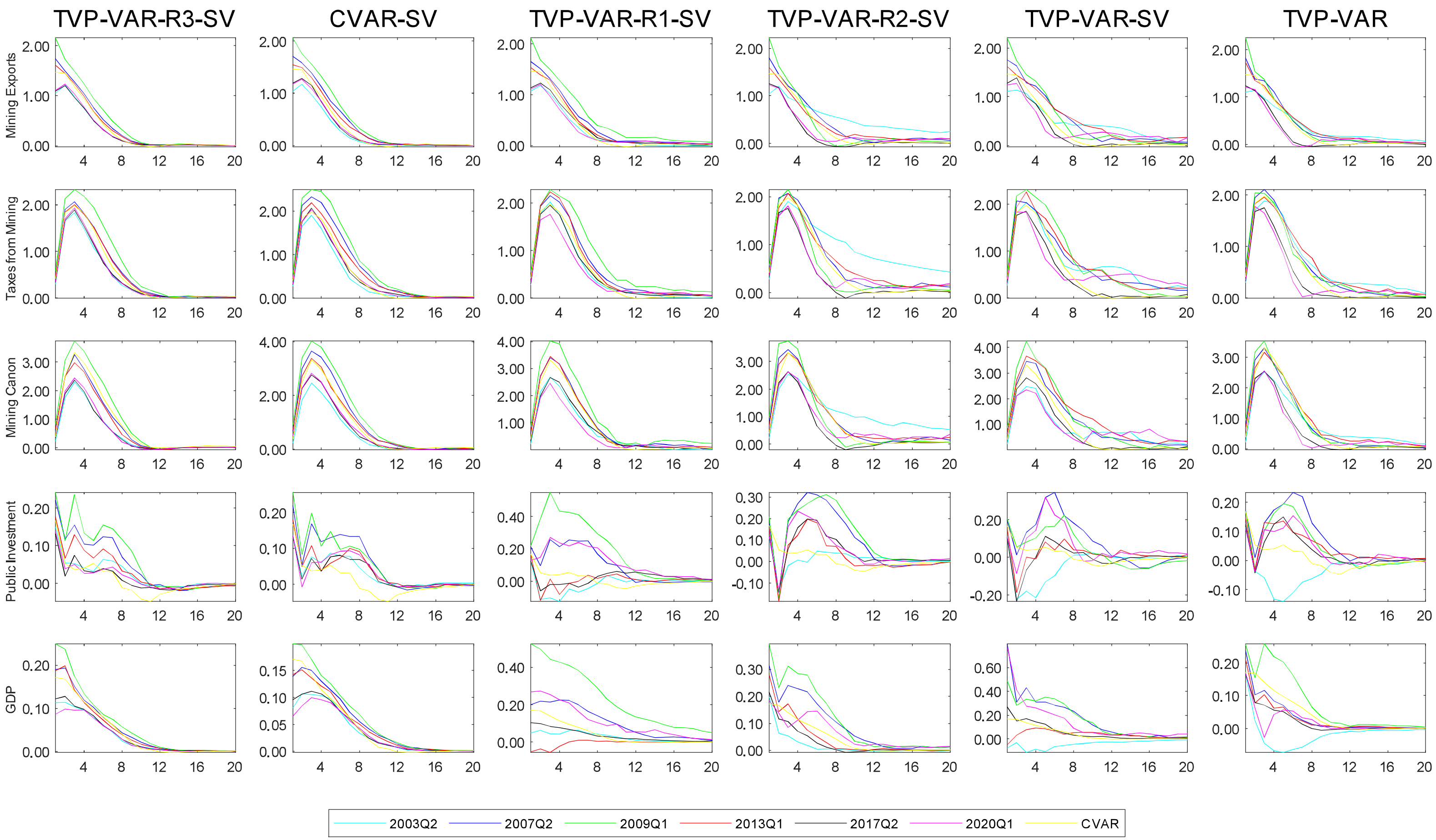

Figure 9. IRFs at Selected Time Periods under Alternative Measure of Mineral Commodity Prices.

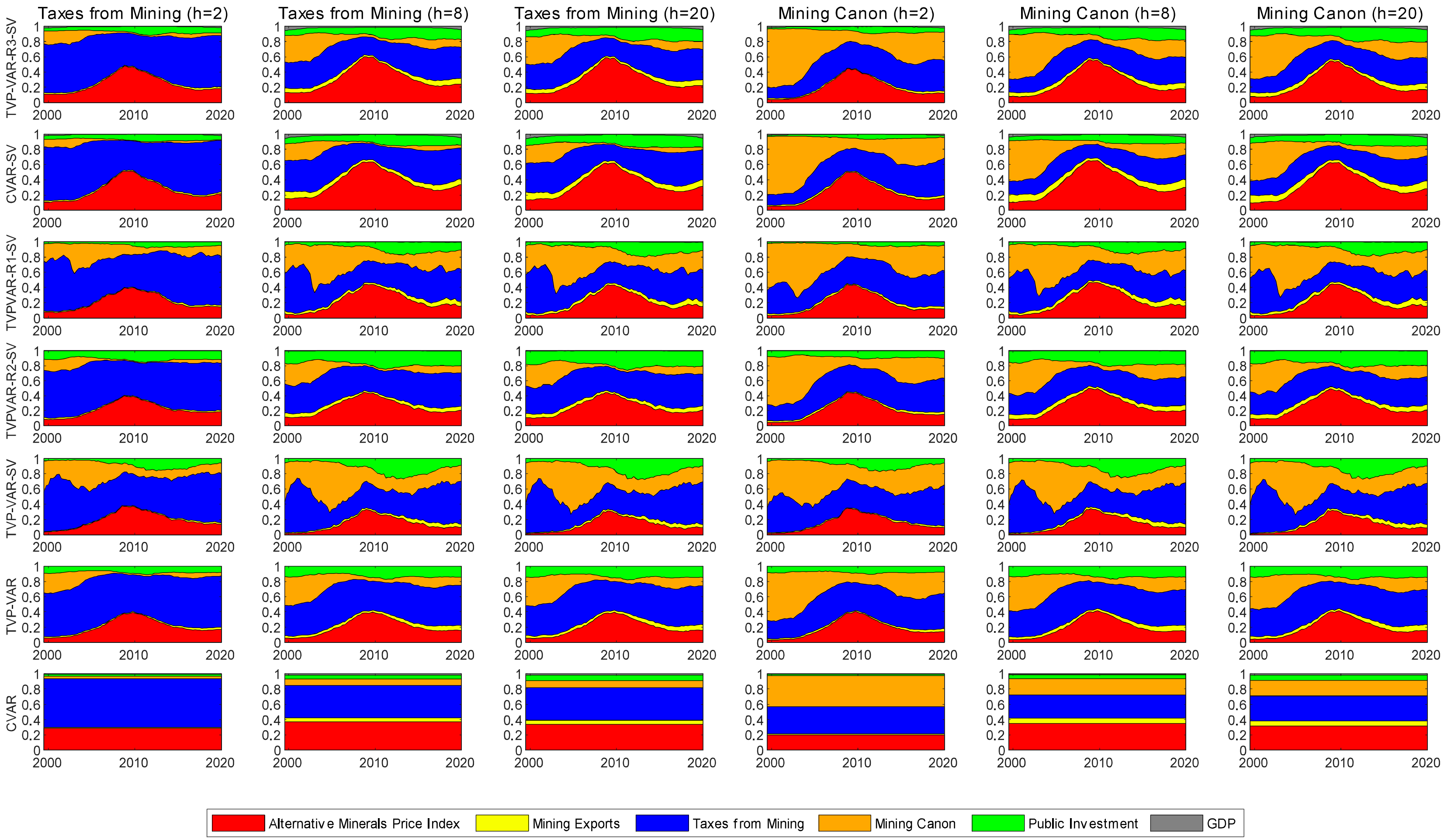

Figure 10. Time Evolution of the FEVD of Taxes from Mining Growth and Mining Canon Growth for All Models at Different Horizons under Alternative Measure of Mineral Commodity Prices.

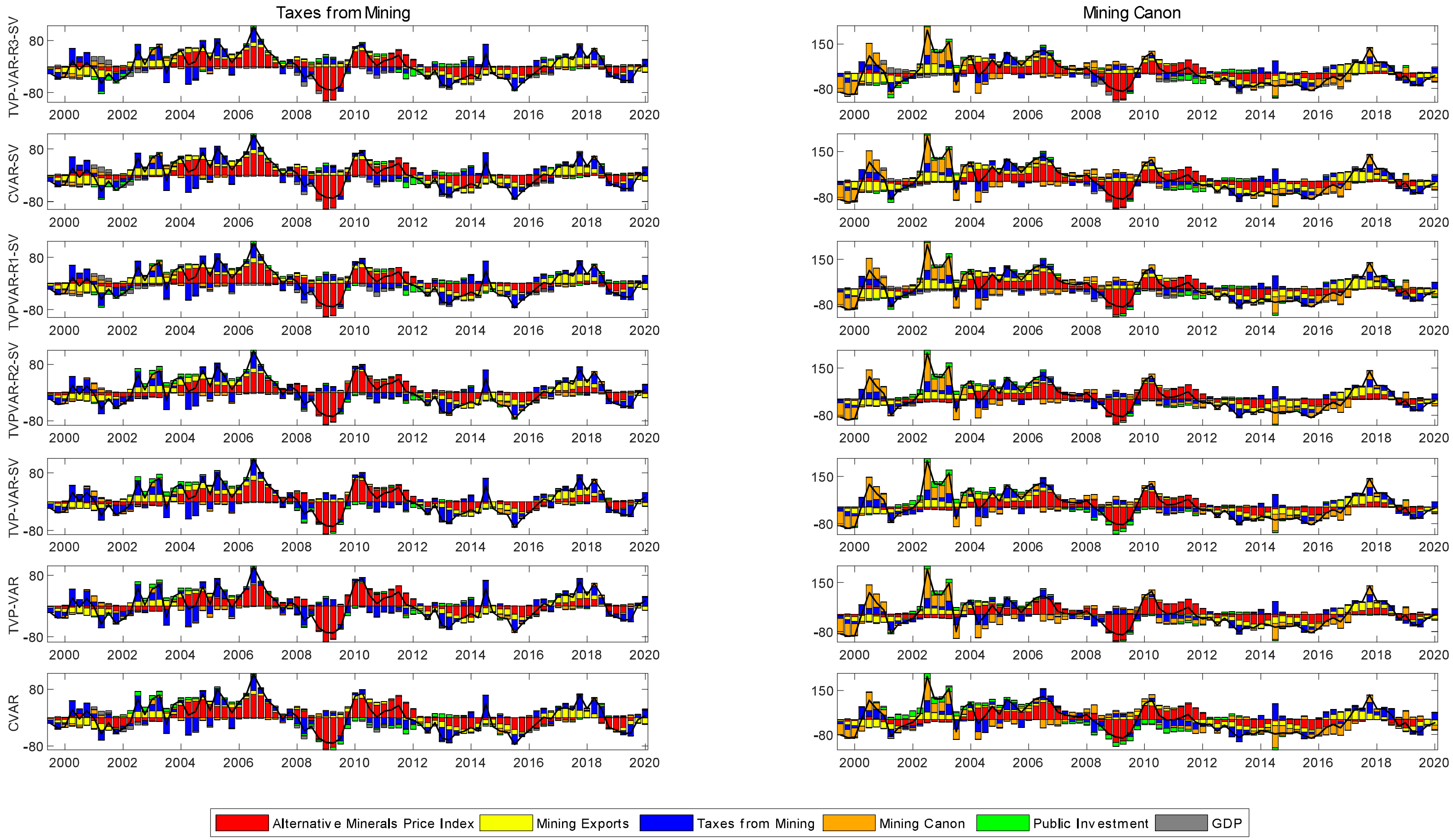

Figure 11. Historical Decomposition of Taxes from Mining Growth and Mining Canon Growth for All Models under Alternative Measure of Mineral Commodity Prices.

CONCLUSIONS

This section presents the main conclusions drawn from the two previous chapters. The first study presents empirical evidence on the effects of corruption on economic growth, human development and the natural resources sector in Latin American and Nordic countries. The analysis is conducted by estimating a hierarchical Bayesian panel VAR model given that this method allows us to use efficiently the information by exploiting the heterogeneity across countries.

The results reveal some relevant contrasts between both regions. In Latin America there is mixed evidence regarding the impact of corruption on growth since there is support for the sand the wheels hypothesis in Bolivia and Chile, support for the grease the wheels hypothesis in Colombia and no significant impact of corruption on growth in Brazil and Peru. By contrast, the response of growth to shocks in corruption is significantly negative in all Nordic countries. In turn, it is found that shocks in corruption negatively affect human development in all countries from both regions. Corruption tends to spur natural resources sector in Latin American countries, especially in Brazil, Colombia and Peru, which suggests that corruption could be "facilitating" extractive operations in these countries. By contrast, corruption is detrimental for the activity of the natural resources sector in all Nordic countries. Then, robustness checks were applied considering alternative specification of hyperparameters, priors and ordering of the variables. It is found that most of the patterns observed in the baseline model remain under these new specifications.

In addition, two alternative methodological approaches are considered. Firstly, a panel error correction VAR model is estimated and it is found that in Latin American countries corruption does not cause economic growth but it does cause natural resources exports. Besides, in Nordic countries corruption have a causal impact on economic growth. Secondly, asymmetric effects are introduced by distinguishing between positive and negative shocks in corruption. The results corresponding to positive corruption shocks are in line with those of our baseline model. In turn, the results corresponding to negative corruption shocks show interesting patterns. In Latin American countries negative corruption shocks have a significantly positive impact on economic growth, so that these countries may spur economic growth by increasing the transparency of their institutions and procedures. By contrast, in Nordic countries negative corruption shocks do not have a significant impact, which is consistent with the idea that increases in transparency do not represent a substantial alteration for these countries since they are already recognized as the most transparent in the world.

In terms of policy recommendations, the results of this paper suggest that Nordic countries must continue to strive to avoid corruption because, precisely due to their high level of transparency, increases in corruption represent a substantial alteration regarding how they normally operate and, consequently, become particularly harmful for these economies. In turn, Bolivia and Chile could increase their level of economic growth by reducing corruption given that evidence for the sand the wheels hypothesis is found in these countries. In turn, special attention should be given to corruption issues in the natural resources sector of Brazil, Colombia and Peru, where natural resources exports respond positively to shocks in corruption. In addition, regardless the issue of the "grease" versus the "sand the wheels" debate, governments should seek to reduce corruption because, despite corruption can have mixed effects on economic growth in some contexts, it is anyway harmful for human development.

The second study, included in chapter two, shows evidence about the evolution of the effects of mineral commodity prices on fiscal variables in Peru. The analysis is conducted by estimating a TVP-VAR-SV model, which is compared with alternative specifications by means of the marginal likelihood and the DIC. The results show that considering stochastic volatility is essential in order to correctly capture the dynamics of the system. The preferred model is the one in which only the intercepts and the variance are time-varying (TVP-VAR-R3-SV).

The IRFs show that the impact of mineral commodity prices on fiscal fluctuations is more than proportional since an increase of 1% in the growth of mineral commodity prices generates increases of around 1.5% and 2.5% in the growth of taxes from mining and mining canon. In addition, it is found that the response of taxes from mining and mining canon to shocks in mineral commodity prices is increasingly more pronounced until reaching a peak around 2009 and then decrease, which is in line with the dynamics of the commodities boom. Regarding the FEVD, the importance of shocks in mineral commodity prices growth in explaining the growth of taxes from mining and mining canon increases in line with the increase of those prices until reaching a peak during the Great Recession, where shocks in mineral commodity prices explain between 40% and 50% of fluctuations in taxes from mining and mining canon, and then decreases with the end of the commodities super cycle. Concerning the HD, it is found that the dynamics of taxes from mining and mining canon is driven by shocks in mineral commodity prices to a great extent, especially in 2009, where the decline in those prices generated a great reduction in fiscal revenues. It must be noted that mining canon is also explained to a great extent by its own shocks in the first years, which is associated with legal changes regarding its determination. These results are robust to an alternative measure of mineral commodities prices, different priors, and another ordering of the variables.

In terms of recommendations, since our results show the importance of considering a time-varying structure for correctly modelling the impacts of shocks in mineral commodity prices, policy-makers should integrate time-varying parameters and, more importantly, stochastic volatility in their forecast equations of fiscal variables. In this way, they may incorporate the particularities of the economic context in order to better measure the magnitude of shocks in mineral commodity prices and adjust the fiscal framework according to it. They also could consider alternative identification schemes. On the other hand, since there is a remarkable vulnerability of taxes from mining and mining canon to shocks in mineral commodity prices so that they have a very remarkable fall when these prices decrease, Peruvian authorities should seek alternatives to shelter the economy from fluctuations in mineral commodity prices. Thus, in line with the recommendations of Consejo Fiscal (2017), they should promote productive diversification by facilitating and supporting the expansion of sectors different from mining in order to bolster the resilience of the economy to external shocks, especially those in mineral commodity prices.

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