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# The role of economic development for the effect of oil market shocks on oil-exporting countries. Evidence from the interacted panel VAR model

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ABSTRACT

This paper examines whether the effects of oil market shocks on economic activity and exchange rates in oil-exporting countries depend on the stage of economic development or the scale of oil exports. Within the framework of block-exogenous Interacted Panel Vector Autoregression (IPVAR), we show that both oil price and oil price uncertainty shocks affect the economies of oil-exporting countries. The responses of domestic variables to oil market shocks are heterogeneous across countries and the scale of these responses depend on the level of economic development. In general, the reaction of emerging market economies is more prominent than that of advanced economies. The combined contribution of oil market shocks to exchange rate volatility is inversely associated with the stage of economic development, but no such relation is observed for industrial production. The results obtained are robust to conditioning the responses on the scale of oil exports, restricting the sample to the non-covid pandemic period, and using the alternative measure for oil price uncertainty.

## 1. Introduction

Oil price shocks have been considered to be an important source of macroeconomic fluctuations, at least since the oil crises of the 1970s. Since that time, considerable research effort has not yet led to a consensus on what are the economic effects of oil price fluctuations. The discussion on this topic in the literature, which we attempt to contribute to in this article, can be grouped into three key threads.

The first one focuses on the potential reasons behind the diminished susceptibility of the economy to oil price shocks. The debate goes back to Blanchard and Galí's (2010) finding that oil price gyrations in the 2000s were associated with milder movements in output and inflation compared to those observed in the 1970s. Blanchard and Riggi (2013) claim that a smaller share of oil in production and consumption, lower real wage rigidity, and better monetary policy contributed to this change in the causal relation from the price of oil to macroeconomic variables. Next, Oladosu et al. (2018), within a meta-regression analysis framework, examine whether the elasticity of GDP with respect to oil prices in oil-importing countries depends on structural characteristics (e.g. real GDP per capita, net petroleum import-energy use ratio) and the nature of oil shocks. Apart from confirming that the elasticity has decreased over time, they also explain why differences in the structure of the economy across regions are important in this respect.

The second line of research investigates the effects of oil price uncertainty shocks rather than disturbances to the oil price level. The main argument in this debate is that oil price volatility implies unanticipated changes in future oil prices, hence inducing firms and households to postpone their expenditures (Bernanke, 1983; Hamilton, 2003). Elder and Serletis (2009, 2010) find that elevated oil price uncertainty adversely affects output, investment and durable consumption in Canada and the United States. Interestingly, they also discuss why low uncertainty in the 2000s made oil price increases less costly to the real economy. Similarly, Bashar et al. (2013) show that increased oil price uncertainty exerts a strongly negative and lasting effect on Canadian output, which resembles that of the adverse demand shock and overshadows the effect of the oil price level shock. In general, oil uncertainty shocks are found to be an important source of output variability for numerous oil-exporting (Śmiech et al., 2021) and oil-importing countries (Maghyereh et al., 2019). Finally, it can be noted that oil uncertainty shocks are significantly squeezing economic activity even if one controls for other sources of uncertainty (Gao et al., 2021).

The third group of studies investigates whether global economic

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activity is an important driver of oil price fluctuations (see, e.g., Baumeister and Kilian, 2016; Kilian and Murphy, 2014). These studies usually decompose the dynamics of oil prices into idiosyncratic components and those related to global demand shocks (Kilian, 2009). It can be noted that for the last two decades the latter have become increasingly related to developments in emerging market economies, especially Asian countries (Aastveit et al., 2015). In this discussion, it is worthy to mention that in a recent study, Caldara et al. (2019) show that supply and demand factors are equally important in explaining oil market fluctuations.

Our paper contributes to these three threads by examining the effects of oil price level and uncertainty shocks on oil-exporting economies. Even though there are some studies on the performance of oil-exporting countries in the face of oil shocks, their number is still relatively low in comparison to the abundant research on oil importers. Thus, we review these studies and provide new evidence on the effects of oil market shocks in seven oil producers: Brazil, Canada, Colombia, Mexico, Norway, Russia, and the United Kingdom. Using the Interacted Panel Vector Autoregression (IPVAR) framework adjusted for block exogeneity restrictions, we identify global and country-specific shocks. Next, we examine the set of responses of industrial production and the real exchange rate to oil price uncertainty and level as well as global demand shocks. Given that in the IPVAR model impulse response functions are allowed to vary with countries' characteristics, we can explore if economy reaction to global disturbances depends on the stage of economic development.

Our main findings can be summarised as follows. First, in line with the literature, we show that oil-exporting countries are susceptible not only to oil price level and global demand disturbances but also to oil price uncertainty shocks. Second and more importantly, we demonstrate that the responses of domestic variables to global shocks are heterogeneous across countries and that the scale of the reaction, but not its direction, depends on the level of economic development. In general, the responses of emerging market economies are more pronounced than those of advanced economies. Third, we show that the combined contribution of oil market shocks to exchange rate volatility is inversely associated with the stage of economic development, but such relation is not observed for industrial production. Fourth, sensitivity analyses confirm that the above results are robust to conditioning the responses on the scale of oil exports, restricting the sample to the non-covid period or using the alternative measure for oil price uncertainty.

Our main contribution to the literature is that we are the first to investigate the role of economic development for the effects of oil market shocks on output and exchange rate within a formal framework of the IPVAR model. This methodology allows us to embed country characteristics, such as the stage of economic development or the scale of oil exports, directly into the VAR system and use them in a very flexible way to condition the impact of global oil market shocks on domestic variables. In our paper, we go beyond the standard divide into the oil-importing and oil-exporting countries and demonstrate that country characteristics of the latter group indeed shape the susceptibility of a macroeconomy to oil shocks. The level of economic development used as an interactive variable can be considered as a proxy of more detailed country characteristics such as the quality of institutions, the credibility of monetary policy or energy share in consumption. Two other features of our approach merit mentioning. First, drawing on the debate on the choice of oil price uncertainty measure, we use both the crude oil volatility index (OVX) and the conditional variance of oil prices obtained from a GARCH model. Second, given the potential endogeneity of oil shocks to global economic activity propelled to an increasing extent by the rise of the emerging market economies, the global demand shocks are modelled as unexpected changes in the global activity index proposed recently by Baumeister and Hamilton (2019). The index aggregates the evolution of industrial production both in OECD member states and six big non-OECD countries. These two features of our approach make it possible to disentangle the effects of conventional oil price shocks from those of oil uncertainty shocks and global demand shocks.

The rest of the paper is organised as follows. In the next section, the relevant literature is reviewed. The details of the IPVAR framework employed to identify global and country-specific shocks are described in Section 3. Data and the basic characteristics of countries included in the sample are presented in Section 4. Empirical findings on the importance of global shocks for industrial production and exchange rate fluctuations and results of sensitivity analyses are reported in Sections 5 and 6, respectively. The last section concludes.

## 2. Related literature

This section discusses the main findings reported in the literature on the economic effects of oil price uncertainty (henceforth, OPU) shock. We review studies that examine how these disturbances affect economic activity (e.g. industrial production and real GDP), monetary policy variables (interest rates and exchange rates) as well as price developments (inflation). We abstract from reviewing studies on the role of oil price shocks as this kind of discussion can be found in a number of other studies (Bergmann, 2019; Berument et al., 2010; Jiménez-Rodríguez and Sánchez, 2005).

The studies on the effects to OPU shocks can be divided using various criteria. Looking at country characteristics, most studies focus on net oil-importers, especially the United States (Elder, 2020; Elder, 2018; Elder and Serletis, 2010; Serletis and Xu, 2019; Thiem, 2018), but also South Africa (Chiweza and Aye, 2018), Jordan and Turkey (Maghyereh et al., 2019), Turkey (Güney, 2020; Köse and Ünal, 2021) or China (Cheng et al., 2019). Some authors examine oil-exporting countries, mainly Canada (Bashar et al., 2013; Elder, 2021; Elder and Serletis, 2009), Malaysia (Ali Ahmed and Wadud, 2011), or Mexico, Canada, Russia and Norway together (Śmiech et al., 2021). There are also studies that focus on a group of countries at a similar level of economic development, such as European Union member states (Balashova and Serletis, 2021; Živkov et al., 2020), OECD countries (van Eyden et al., 2019; Yin and Feng, 2019), six developed European economies (Živkov et al., 2020), or emerging economies (Bilgin et al., 2015, Azad and Serletis, 2022). However, these studies provide only a generic answer to the question on whether the response of domestic variables to OPU shocks depends on the level of economic development.In principle, these studies report the results obtained from individual country models and conduct an informal analysis of the topic, e.g. as it was done by Śmiech et al. (2021) using the structural VAR framework.

One of the key messages from the above studies is that, regardless of country characteristics, there is usually a negative and significant impact of OPU shocks on the real sector of the economy. This finding holds for various measures of economic activity, such as industrial production or its components[1] (Bashar et al., 2013; Chiweza and Aye, 2018; Elder, 2018; Elder and Serletis, 2009; Güney, 2020; Jo, 2014; Maghyereh et al., 2019; Śmiech et al., 2021; Thiem, 2018; Živkov et al., 2020), real GDP (Cheng et al., 2019; Serletis and Xu, 2019; van Eyden et al., 2019) or total factor productivity (Balashova and Serletis, 2021). As regards more detailed results, van Eyden et al. (2019) indicate that the negative impact of OPU shocks on output is more severe for oil-exporting than oil-importing countries. Azad and Serletis (2022) also report differences across countries, namely that a rise in OPU leads to output decline in India, Indonesia, Mexico, Russia, and Turkey, but output increase in Brazil and China. In turn, Güney (2020) points to asymmetries, i.e. that economic activity responds more to decreases rather than increases in OPU. Finally, Gao et al. (2021) demonstrate that the negative effect of OPU on GDP remains significant even if one

[1] Elder and Serletis (2010) notice that "industrial production is a much narrower measure of economic activity than real GDP but is a common measure of output available at the monthly frequency".

accounts for traditional measures of uncertainty.

As regards the response of monetary variables to OPU shocks, the results in the literature are ambiguous. In particular, the reaction of interest and exchange rates to OPU shocks seems to depend on whether a country is exporting or importing oil. For oil-exporting countries (Malaysia and Canada) Ali Ahmed and Wadud (2011) and Bashar et al. (2013) find that OPU shocks lead to exchange rate depreciation as well as interest rates and inflation declines. Śmiech et al. (2021), who consider four oil-exporting countries, report that OPU shocks trigger a long-lasting depreciation of Mexican and Russian currencies, but this is not the case for Canadian dollar and Norwegian krone. On the contrary, in studies for oil-importing countries (e.g. South Africa, China, or Turkey) OPU shocks are usually leading to higher inflation and exchange rate appreciation (Cheng et al., 2019; Chiweza and Aye, 2018; Güney, 2020). In contrast, OPU shocks tend to result in higher money supply, regardless of country characteristics (Bashar et al., 2013; Cheng et al., 2019; Güney, 2020). Overall, it seems that central banks use expansionary monetary policies to stimulate the economy after OPU increases.

Finally, it can be mentioned that the econometric methodology used to examine the effects of OPU shocks on economic activity varies across studies. Some authors employ the standard structural VAR framework (Bashar et al., 2013; Chiweza and Aye, 2018; Köse and Ünal, 2021), its Bayesian version (Cheng et al., 2019; Jo, 2014; Śmiech et al., 2021), models extended for the multivariate GARCH-in-mean effect (Elder, 2020, Elder, 2018; Elder and Serletis, 2010, Elder and Serletis, 2009; Azad and Serletis, 2022; Serletis and Mehmandosti, 2019; Thiem, 2018), the bivariate GARCH-in-mean VAR (Maghyereh et al., 2019) or Markov switching structural GARCH-in-mean VAR models (Serletis and Xu, 2019). There are also a handful of papers investigating the impact of oil price fluctuations on economic activity using dynamic panel analysis (Bilgin et al., 2015; Rafiq and Salim, 2014; van Eyden et al., 2019; Yin and Feng, 2019), including panel VAR framework (Bergmann, 2019; Omojolaibi and Egwaikhide, 2014).

## 3. Methodology

From a methodological point of view, we apply the Interacted Panel VAR (IPVAR) framework introduced to the literature by Towbin and Weber (2013). IPVAR model allows us to embed country characteristics, such as the stage of economic development or the scale of oil exports, directly into the VAR system and use them in a very flexible way to condition the impact of global oil market shocks on domestic variables. The IPVAR model has been successfully applied in a number of recent studies to analyse the role of institutional variables for the dynamics of economic systems in response to structural shocks. The analyses were related to the response of the economy to external (Abbritti and Weber, 2018; Sá et al., 2014; Towbin and Weber, 2013), fiscal (Amendola et al., 2020; Huidrom et al., 2020; Ianc and Turcu, 2020; Nickel and Tudyka, 2014), monetary (Hjortsoe et al., 2018), demand (Kouretas et al., 2020) or financial (Leroy and Lucotte, 2019; Leroy and Pop, 2019) shocks. There are also two studies examining the effects of oil price shock on the economy within the IPVAR framework. Abbritti and Weber (2018) used a monetary IPVAR model with three endogenous (unemployment rate, inflation and the interest rate) and a set of interaction variables describing the characteristics of the labour market institutions to show that these institutions have impact on the shape of unemployment reaction to oil price shocks in the sample of 20 OECD countries and years 1970–2013. In turn, Bergmann (2019) used an IPVAR model to assess the impact of oil price shocks on GDP, employing the share of oil in the energy mix as an interaction variable. On the basis of data for 12 countries over the period 1971–2016, the author shows that a decrease in the dependency on oil leads to the weakening in the relationship between oil price changes and GDP growth.

In comparison to the above studies, we differ in terms of the specification of the IPVAR model. In particular, we extend the analysis by investigating the role of OPU shocks with the special emphasis put on the role of economic development. The reaction of the economy to global oil market shocks is assessed within the block-exogenous IPVAR model describing the dynamics of five variables: oil price uncertainty ($oilu_t$), the real price of oil ($oilp_t$), the log of global industrial production ($gx_t$), the log of domestic industrial production ($x_{it}$) as well as the log of the real effective exchange rate of domestic currency ($q_{it}$), where indices $i$ and $t$ refer to country and time period. We divide these variables into external $\mathbf{s}_{it}$ and endogenous $\mathbf{y}_{it}$ variables, so that:

$\mathbf{s}_{it} = (oilu_t, oilp_t, gx_t)'$ and $\mathbf{y}_{it} = (x_{it}, q_{it})'$.

Next, we estimate the model of representation similar to the one adopted by Abbritti and Weber (2018):

$$\begin{bmatrix} C_0 & 0 \\ B_{0i} & A_{0i} \end{bmatrix} \begin{bmatrix} \mathbf{s}_{it} \\ \mathbf{y}_{it} \end{bmatrix} = \begin{bmatrix} \mu^s \\ \mu_i^y \end{bmatrix} + \sum_{l=1}^{L} \begin{bmatrix} C_l & 0 \\ B_{li} & A_{li} \end{bmatrix} \begin{bmatrix} \mathbf{s}_{i,t-l} \\ \mathbf{y}_{i,t-l} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\epsilon}_{it}^s \\ \boldsymbol{\epsilon}_{it}^y \end{bmatrix} \tag{1}$$

In the above notation $\boldsymbol{\epsilon}_{it}^s = (\epsilon_t^{oilu}, \epsilon_t^{oilp}, \epsilon_t^{gx})'$ is the vector of uncorrelated global shocks that are common to all analysed economies and $\boldsymbol{\epsilon}_{it}^Y = (\epsilon_{it}^x, \epsilon_{it}^q)'$ is the vector of idiosyncratic local shocks. In model (1) we impose a set of zero restrictions on model parameters. In particular, we take for granted that local variables do not Granger cause global variables by setting block-exogeneity restrictions for autoregressive parameters. We also assume that $C_0$ and $A_{0,\,i}$ are lower triangular matrices, which implies the recursive identification scheme.

In the equation for external variables, the vector of constants $\mu^s$, the identification matrix $C_0$ as well as autoregressive matrices $C_l$ are the same for all countries and do not depend on the index $i$. This ensures that the dynamics of global vector $\mathbf{s}_{it}$ is described by a traditional VAR model and is the same for all analysed countries. We use this VAR model to select the maximum lag $L$. In particular, we set $L$ to four months on the basis of the Akaike information criterion.[2]

As regards the equation for local variables $\mathbf{y}_{it}$, all parameters depend on index $i$, which means that impulse-response functions of these variables to structural shocks might vary among economies. One of the simplest ways to explore this heterogenous response of $\mathbf{y}_{it}$ to shocks would be to compute separate VAR models for each country and interpret the results in terms of various country characteristics. In fact, this strategy has been applied to system (1) in the recent paper by Śmiech et al. (2021). The other strategy would be to estimate separate panel VAR models on several sub-samples of countries, chosen using structural variables under investigation. The last option, which we follow in this article, is to estimate the IPVAR model, in which the parameters are allowed to vary with country characteristics $z_{ki}$, so that:

$$A_{li} = A_{l,0} + \sum_{k=1}^{K} A_{l,k} z_{ki} \tag{2}$$

$$B_{li} = B_{l,0} + \sum_{k=1}^{K} B_{l,k} z_{ki} \tag{3}$$

where $l = 0, 1, 2, \ldots, L$ refers to the lag order and $K$ is the number of interactive variables. In the baseline model we focus on one structural variable describing the stage of economic development ($z_{1i}$). In the sensitivity analysis we also explore oil exports intensity ($z_{2i}$). Finally, for vector $\mu_i^Y$ we assume that it just includes a set of country fixed effects.

The recursive structure of model (1) implies that the error terms are

[2] Following the discussion of Hamilton and Herrera (2004), who indicate that the response of GDP to oil shock is the highest after four quarters and who claim that the maximum lag-length in monthly VAR models should be set at values at least 12 months, we have re-estimated the IPVAR model by setting the maximum lag length at 12 months. The results of this exercise, which are available upon request, are not changing the main message from our analysis. The scale and sign of the response of endogenous variables to three global shocks are broadly the same as in the baseline model with four lags. The most pronounced differences are twofold. First, IRFs exhibit a slightly oscillating pattern. Second, the real exchange rate response to global shocks is somewhat stronger and more persistent.

uncorrelated across equations, hence parameters from matrices $A_{l,0}$, $A_{l,1}$ and $A_{l,2}$ as well as $B_{l,0}$, $B_{l,1}$ and $B_{l,2}$ can be estimated equation-by-equation using standard least-squares estimator; see discussion in (Towbin and Weber, 2013). These estimates can be substituted to eqs. (2) and (3) to compute the values of $A_{li}$ and $B_{li}$ for any economy, also hypothetical, characterised be a mix of structural variables $gdppc_i$ and $oilexp_i$. Finally, one can simulate model (1) to check how the vector of local variables $\mathbf{y}_{it}$ reacts to shocks in economies of heterogenous structure.

## 4. Data

We based our study on monthly data covering the period from July 2007 to December 2020 and seven oil-exporting countries: Canada (CAN), Mexico (MEX), Norway (NOR), Russia (RUS), Brazil (BRA), Colombia (COL), and the United Kingdom (GBR). For each country we collect the interaction $\mathbf{z}_i$ and endogenous variables $\mathbf{y}_{it}$. Moreover, we use time series for global variables $\mathbf{s}_{it}$. The description of the variables and the data sources are provided in Table 1.

The seven oil-exporting countries we focus on are chosen for four reasons. First, their economies differ in size. The UK is the largest economy, with a GDP of $2.71 trillion in 2019. The next largest countries, Brazil, Canada, and Russia are characterised by the level of GDP ranging between $1.84 and $1.70 trillion. The smallest economies were Colombia and Norway, with GDP of $0.32 and $0.40 trillion, respectively (Table 2). These countries also differ in their level of economic development. The richest country, Norway, has a GDP per capita of 108% of the level for the United States (average for the period 2010–2019). In contrast, the poorest countries, Colombia, Brazil, and Mexico, have their GDP per capita levels equal to 23%, 26%, and 33% of the US level, respectively. In the International Monetary Fund classification, four countries (Brazil, Colombia, Mexico and Russia) are classified as developing, while the remaining three (Canada, the United Kingdom and Norway) as developed ones. These countries are also characterised by a different size of the oil sector. The oil rent,[3] measured as per cent of GDP, amounts to 9.16% in Russia, 4.81% in Norway, 0.49% in GBR, 1.61% in Canada, and 1.81% in Mexico. The net oil exports in relation to GDP ranges from −0.21% for GBR and 0.46% for Brazil to 7.68% for Russia and 8.49% for Norway (see Table 2), respectively. Importantly, the oil export share is not related to the level of economic development, offering an interesting mix of investigated countries. It can be noted that for four (CAN, MEX, NOR, RUS) out of seven investigated countries, the reaction of domestic economies to the oil market shocks was examined earlier in a similar five-variate structural VAR framework by (Śmiech et al., 2021), hence it is possible to compare our findings to the already known results.

**Table 1**
Variables description.

| Variable | Symbol | Description | Role in model | Source |
|---|---|---|---|---|
| Oil uncertainty | $oilu_t$ | CBOE crude oil volatility *index (OVX)*<br>EGARCH volatility for Brent oil model | $\mathbf{s}_{it}$ | CBOE |
| Global production | $gx_t$ | Global industrial production index<br>(log) | $\mathbf{s}_{it}$ | BH |
| Oil price | $oilp_t$ | Oil Brent spot prices deflated by CPI in the US<br>(log) | $\mathbf{s}_{it}$ | FRED |
| IP | $x_{it}$ | Industrial production index<br>(log) | $\mathbf{y}_{it}$ | MEI |
| RER | $q_{it}$ | Real effective exchange rate<br>(log) | $\mathbf{y}_{it}$ | MEI |
| GDP per capita | $z_{1i}$ | GDP per capita (in PPP) relative to U.S level<br>(average for 2010–2019) | $\mathbf{z}_i$ | MEI |
| Oil intensity | $z_{2i}$ | Net oil exports as a percentage of GDP<br>(average for 2010–2019) | $\mathbf{z}_i$ | EIA |

Notes: $\mathbf{s}_{it}$ – global variable, $\mathbf{y}_{it}$ – country specific variable, $\mathbf{z}_i$ – country specific interaction variable; CBOE: Cboe Global Markets, Inc. FRED: St. Louis FED database; BH: Baumeister and Hamilton (2019); MEI: OECD Main Economic Indicators; EIA: U.S. Energy Information Administration.

**Table 2**
Country characteristics.

| Country | Nominal GDP (tr. USD, 2019) | Oil rents (% GDP, 2019) | GDP per capita (% US level) | Net oil export (% GDP) |
|---|---|---|---|---|
| Brazil | 1.84 | 2.04 | 26 | 0.46 |
| Canada | 1.74 | 1.61 | 81 | 2.64 |
| Colombia | 0.32 | 3.68 | 23 | 5.08 |
| Mexico | 1.27 | 1.81 | 33 | 2.63 |
| Norway | 0.40 | 4.81 | 108 | 8.49 |
| Russia | 1.70 | 9.16 | 45 | 7.68 |
| United Kingdom | 2.71 | 0.49 | 76 | −0.21 |

Notes: Values refer to the average of the 2010–2019 period or 2019 (if indicated).

In the empirical part, we estimate IPVAR models that explain the dynamics of three global and two country-specific variables. The first global variable relates to the global activity index. Following (Baumeister and Hamilton, 2019), we proxied it, by the industrial production index for OECD countries and six major non-member economies (Brazil, China, India, Indonesia, Russia, and South Africa). The other two global variables, the real price of oil and oil price uncertainty represent the developments in the oil market. For the former, we use the spot price of Brent crude oil deflated by the US consumer price index. This series is depicted in the upper-right panel of Fig. 1. For the latter, we use the OVX (Crude Oil Volatility Index), which contains both historical and future (prediction of 30-day volatility of crude oil) volatility information. This index is frequently used as a proxy for oil price uncertainty (see Dutta, 2017; Luo and Qin, 2017; Xiao et al., 2018). The period of publication of the OVX index, from 20 May 2007, determined the time frame for our study. In the sensitivity analyses section, we use the alternative measure of uncertainty, which is calculated as a conditional variance from the EGARCH(1,1) model based on daily data with a skewed t-student distribution of errors.[4] Both oil price uncertainty proxies, each scaled by its sample mean, are presented in the upper-left panel of Fig. 1. Two remarks are warranted here. First, there is a strong positive correlation of 0.91 between the two measures of oil price uncertainty. It can also be seen that their peaks tend to occur simultaneously. Second, there is a negative correlation between oil price level and both oil price uncertainty measures: the correlation coefficient is −0.44 for OVX and − 0.61 for EGARCH based measures, respectively.

To quantity the impact of global variables on the local economy, we focus on two variables: the industrial production (IP) index and the real effective exchange rate (RER) index. The lower-left panel of Fig. 1 presents the former for the seven oil-exporting countries. Importantly, the

[3] Oil rents are measured as the difference between the value of crude oil production at regional prices and total costs of production.

[4] The use of estimated conditional variance in the IPVAR model might be seen as a generated regressor in the spirit of Pagan (1984). Elder (2004) proposed a one-step procedure that eliminates this problem; however, Dossani and Elder (2020) showed that responses to oil price volatility obtained in one-step and two-step procedures are quite similar.

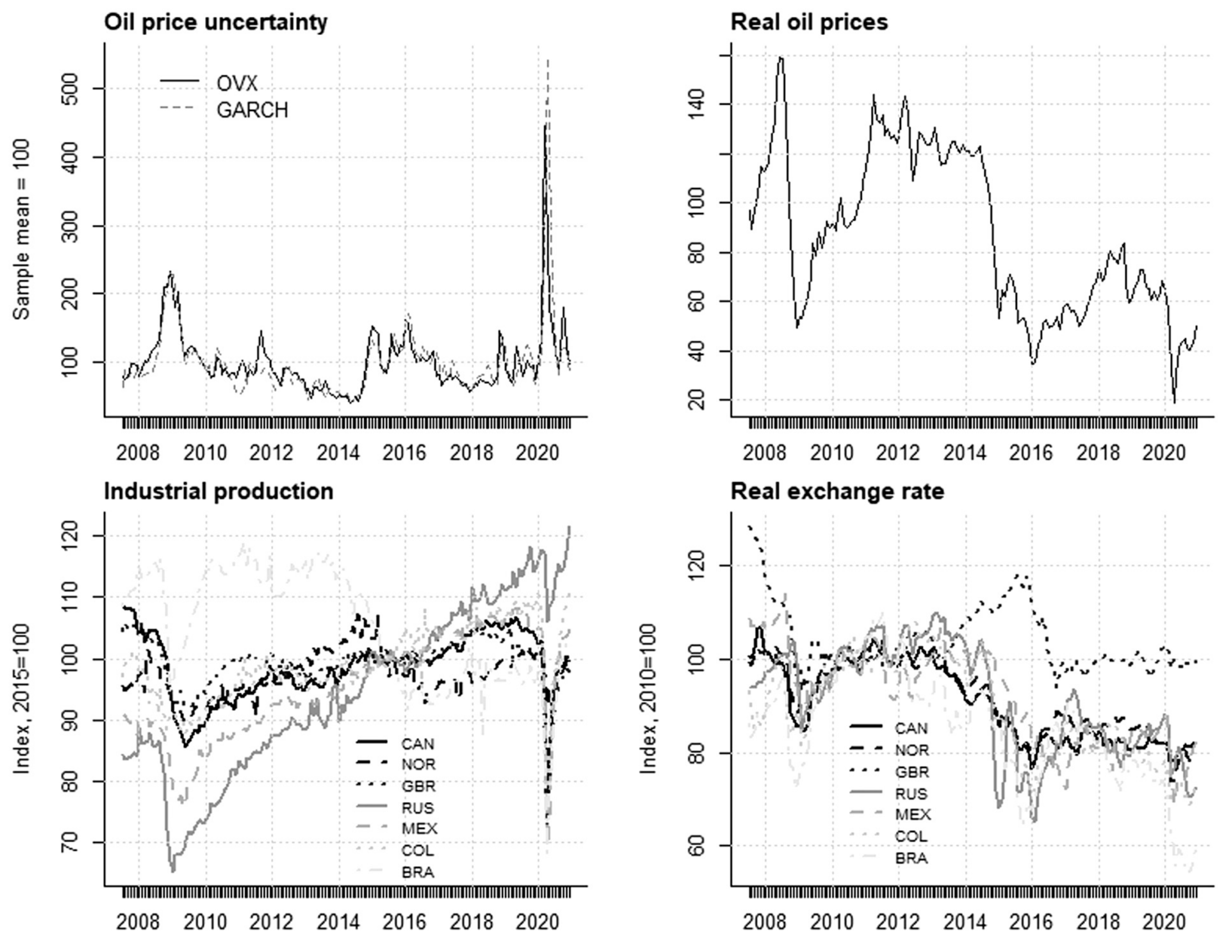


**Fig. 1.** Time series evolution of endogenous variables. Notes: The figure covers the period from July 2007 to December 2020.

IP indices share sharp declines as a result of the global financial crisis and Covid-19 pandemic, with the strongest collapses in industrial production observed in Mexico and Colombia. The lower-right panel of Fig. 1 shows that the common trend is observed in all RER indices, with the exception of the British Pound (GBR). Detailed statistics for both IP and RER series are presented in Table 3. It is worth noting that the average rate of change of IP does not depend on the country's level of development. Positive IP rates of change are observed over the period for Norway, Russia, Mexico and Colombia, and negative for Brazil, Canada, and the United Kingdom. Higher fluctuations of IP rate of change are noticed in three developing countries, i.e. Brazil, Colombia and Mexico. In the case of exchange rates, all countries recorded a depreciation on average. However, in the case of developing countries, much greater exchange rate volatility can be observed.

**Table 3**
Descriptive statistics for local variables.

| | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Industrial Production | | | | | | | |
| Mean | −0.64 | 0.28 | −0.48 | 2.73 | 1.09 | 0.96 | −0.36 |
| Std. Dev. | 8.83 | 5.68 | 10.00 | 7.72 | 13.09 | 12.95 | 12.25 |
| Skewness | −4.21 | 0.15 | −5.72 | −1.93 | −4.05 | −2.85 | −2.72 |
| Kurtosis | 51.95 | 4.78 | 66.74 | 12.00 | 66.53 | 33.69 | 26.82 |
| ACF(1) | 0.17 | −0.33 | 0.09 | 0.03 | 0.18 | −0.03 | −0.01 |
| ACF(2) | −0.28 | 0.04 | −0.25 | 0.09 | −0.35 | −0.25 | −0.09 |
| Real exchange rate | | | | | | | |
| Mean | −1.50 | −1.58 | −1.91 | −1.91 | −2.08 | −1.73 | −2.79 |
| Std. Dev. | 5.88 | 5.76 | 6.12 | 12.67 | 10.21 | 9.70 | 11.66 |
| Skewness | −0.51 | −1.07 | −0.87 | −1.00 | −1.54 | −0.74 | −0.79 |
| Kurtosis | 7.45 | 7.91 | 4.79 | 7.62 | 10.50 | 3.98 | 5.24 |
| ACF(1) | 0.21 | 0.25 | 0.13 | 0.41 | 0.20 | 0.18 | 0.29 |
| ACF(2) | 0.00 | −0.13 | 0.03 | −0.06 | −0.20 | −0.08 | 0.01 |

Notes: The table presents statistics for the logarithmic growth rates of industrial production and real exchange rate indices. The mean value and standard deviation are rescaled so that they refer to annualized growth rates.

## 5. Results

In this section we present the baseline results of our investigation by evaluating how the impact of oil sector shocks on industrial production and the real exchange rate of oil producers depend on the stage of economic development. For that purpose we use the IPVAR model described in Section 3 with one interaction variable ($K = 1$), namely the average level of GDP per capita ($z_{1i} = gdppc_i$).

We start by explaining what we mean by global shocks, which are contained in the trivariate vector $\boldsymbol{\epsilon}_t^s$. We do it by looking at impulse response functions of global variables in vector $\mathbf{s}_t$ to global shocks $\boldsymbol{\epsilon}_t^s$. It should be emphasized that the block exogeneity restriction imposed on the parameters of the IPVAR model ensure that the dynamics of global variables is the same for all analysed economies.

The left panels of Fig. 2 show that the OPU shock is defined as an immediate increase of the OVX index by 10 points and its subsequent, gradual return to the initial level. This disturbance leads to a significant oil price decline, which reaches its trough at around −10% after two months from the shock occurrence. It also results in a decrease of up to −0.8% in global industrial production. Within two years the global economy is almost back to equilibrium. Next, the right panels of Fig. 2 define the oil price shock as a relatively persistent increase in real oil

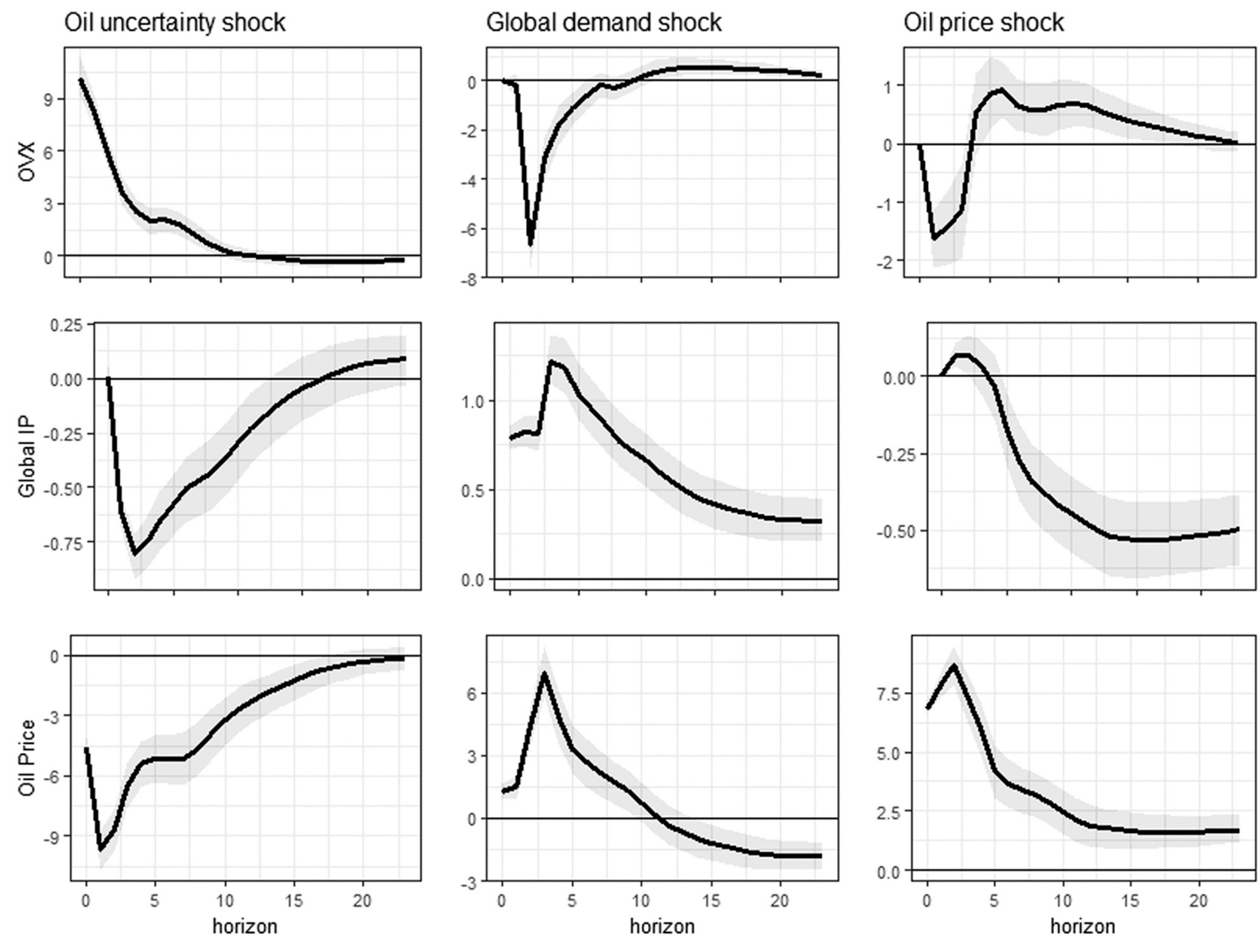


**Fig. 2.** Impulse response function of global variables to global shocks. Notes: The solid lines represent the median response of global variables to global shocks. The shaded areas represent the 90% confidence interval. OVX: oil uncertainty, Global IP: log of global industrial production, Oil price: log of real oil price.

prices, which at the start amounts to about 8%. Initially, this surprise is not harmful for global production and even leads to lower levels of the OVX index. However, in the subsequent periods persistently higher oil prices undermine economic activity and lead to higher perception of oil price uncertainty. Fig. 2 also illustrates how shocks to global industrial production affect the oil market. It can be noted that these reactions of global variables are broadly in line with the studies surveyed in Sections 1 and 2.

We continue by looking at the reaction of two local variables, which are contained in vector $\mathbf{y}_{it}$, to the three global shocks $\boldsymbol{\epsilon}_{it}^{\$}$. In this case, the response is heterogenous, given the structure of the IPVAR model (1). In particular, in the baseline model we assume that this response depends on the level of economic development. Below, we describe the effect of global shocks on each economy separately and then compare two hypothetical economies, characterised by high and low level of economic development.

As regards individual responses, the left panels of Fig. 3 indicate that the oil uncertainty shock leads to a decline in industrial production and real exchange rate depreciation in all countries. Even though the immediate depreciation of the exchange rate is in line with the results of Bashar et al. (2013), the subsequent dynamics are heterogenous. The depreciation of the exchange rate in developing countries (light grey lines) is sizeable and long-lasting. On the contrary, in developed countries (dark grey lines) the exchange rate gradually appreciates and quickly returns to the pre-shock level. As regards the reaction of industrial production, it is much more pronounced in developing countries in the initial periods, but the persistence of the reaction is comparable. These distinct reactions might result from different effectiveness of the resource funds in these countries as well as to the fact that investors' confidence is related to the economic development level (Koh, 2017).

The right panel of Fig. 3 illustrates the reaction of the analysed economies to the oil price shock. One can observe a delayed and negative effect of oil prices on economic activity, which is in line with the results of Śmiech et al. (2021). The scale of the decline is higher in developing countries, which might be partially explained by the Dutch disease channel. Actually, the oil price shock leads to a relatively high appreciation of developing countries' currencies.

As regards the response of oil producers to the global demand shock, the middle panel of Fig. 3 shows that the reaction of industrial production seems intuitive and confirms high synchronization of economic activity across countries after the global demand shocks. It can be added that the strength of the reaction is higher for the group of developing countries. On the contrary, the reaction of exchange rates is more diverse. In developed countries, the initial appreciation is small and quickly turns into depreciation. In developing countries, the initial appreciation is more pronounced and long-lasting.

Fig. 3 demonstrates unambiguously that the response of industrial production and real exchange rate to global oil market disturbances is more pronounced in developing than developed countries. This might be due to the generally higher variability of these variables in countries at lower stages of development (see Table 2) or the higher susceptibility of these economies to global oil market shocks. The best way to assess whether the latter is true is to calculate the combined contribution of oil uncertainty and oil price shocks to the forecast error variance (FEV) of both variables.

The FEV decomposition is presented in Table 4. Its upper panel

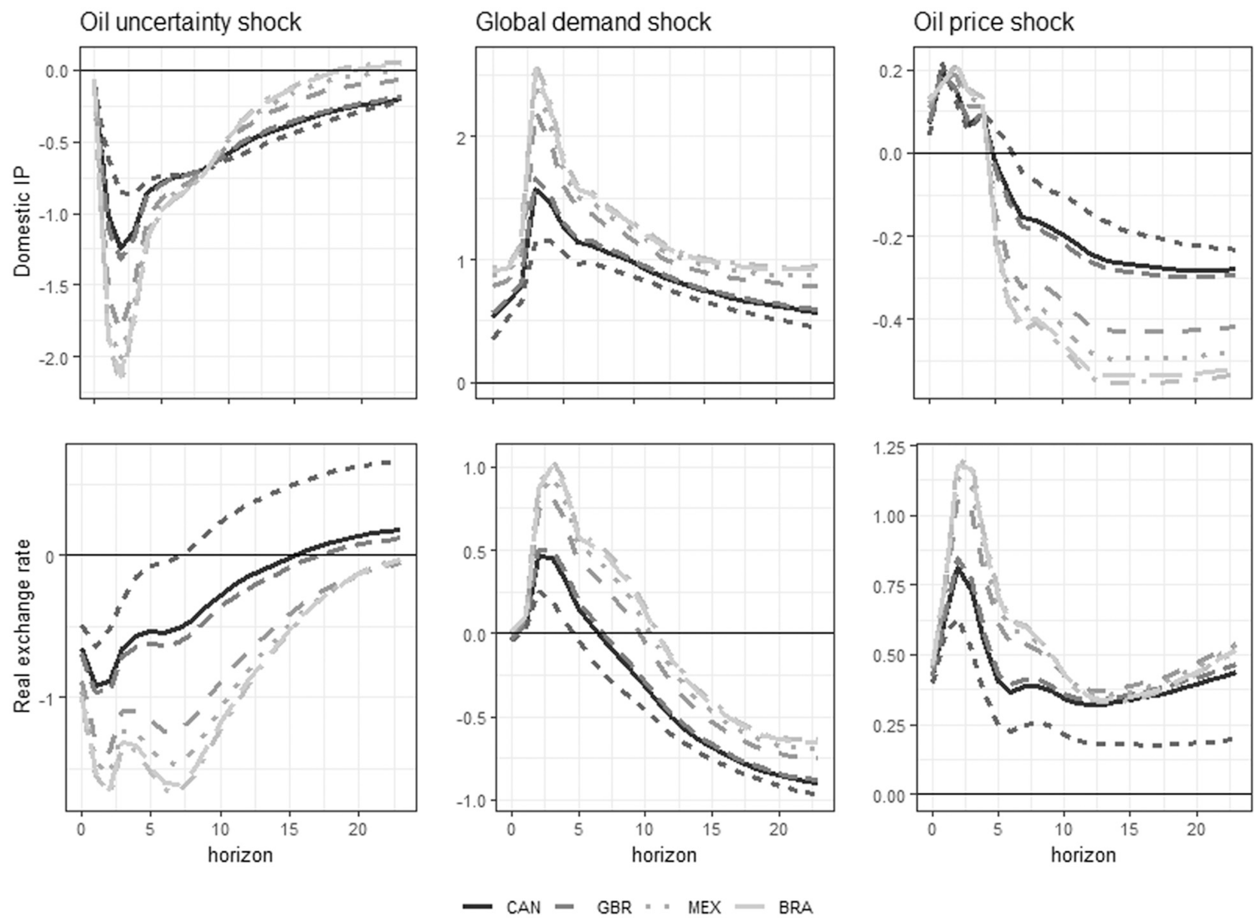


**Fig. 3.** Impulse response function of local variables to global shocks. Notes: Domestic IP: log of domestic industrial production (in %), Real exchange rate: log of the real effective exchange rate (increase stands for appreciation of domestic currency, in %).

**Table 4**
Contribution of oil market shocks to forecast error variance.

| Horizon | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Industrial Production | | | | | | | |
| 1 | 0.2 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 |
| 3 | 21.7 | 11.5 | 23.7 | 35.9 | 40.0 | 43.0 | 42.2 |
| 6 | 21.4 | 16.4 | 22.4 | 27.7 | 29.5 | 30.7 | 30.4 |
| 12 | 20.3 | 18.5 | 20.7 | 23.5 | 24.5 | 25.3 | 25.1 |
| 24 | 18.8 | 19.0 | 18.9 | 20.0 | 20.6 | 21.3 | 21.1 |
| Real exchange rate | | | | | | | |
| 1 | 11.2 | 7.7 | 11.9 | 16.8 | 18.7 | 20.3 | 19.9 |
| 3 | 16.4 | 9.8 | 17.8 | 26.8 | 30.3 | 33.0 | 32.2 |
| 6 | 16.5 | 8.1 | 18.4 | 30.7 | 35.1 | 38.4 | 37.5 |
| 12 | 14.9 | 5.5 | 17.6 | 37.4 | 44.2 | 48.9 | 47.7 |
| 24 | 12.6 | 6.7 | 15.4 | 37.4 | 44.6 | 49.2 | 48.0 |

Notes: The table presents the combined share of oil price and oil uncertainty shocks in forecasts error variance of variables expressed as the logs of level.

shows that oil market disturbances are an important source of industrial production fluctuations in all analysed countries. At two-year horizon, their share in the FEV amounts to around 20% and is broadly independent of the stage of development. On the contrary, at horizons of between 3 and 6 months, oil market shocks are a more important source of economic fluctuations in developing than in developed countries. Similarly, the bottom of Table 4 makes it clear that the contribution of oil market shocks to real exchange rate volatility is higher for countries at a lower stage of economic development. Just to illustrate, at two-year horizon their contribution to real exchange rate FEV amounts to almost 50% in Colombia and Brazil, and is more than three times smaller in Norway and Canada.

So far we have shown that within the IPVAR system individual countries at lower stages of economic development tend to react stronger to oil market shocks than individual advanced economies. Here, we complement this analysis by comparing the reaction to global shocks of two hypothetical economies, characterised by high and low level of economic development. We assume that the "rich" economy is characterised by GDP per capita at 95% of the US level, which is the average value for the two richest economies in our sample (Norway and Canada). For the "poor" economy we set the ratio at 25%, which is the mean for the two poorest countries (Brazil and Colombia).

In practical terms, we proceed as follows. Given the estimates of IPVAR model parameters, we use the assumed values of the interaction variable ($z_{rich} = 0.95$ and $z_{poor} = 0.25$) in eqs. (2) and (3), and substitute the computed matrices to structural VAR model (1). Next, we simulate this model to calculate the impulse response functions. Moreover, to calculate if differences in the response functions are significant, we generate 1000 artificial series from estimated model (1) and use them to calculate bootstrapped confidence interval. Moreover, for each simulated series we can calculate the difference in the impulse-response function. This allows us to evaluate whether the responses of industrial production and the real exchange rate to global shocks are significantly different between the hypothetical rich and poor economies.

Fig. 4 outlines the reaction of the two hypothetical economies to the global shocks. For each impulse response function we present two graphs. On the first one we depict the median response and the corresponding 90% confidence bands for the rich (black shaded area) and poor (red shaded area) economies. The second graph shows the

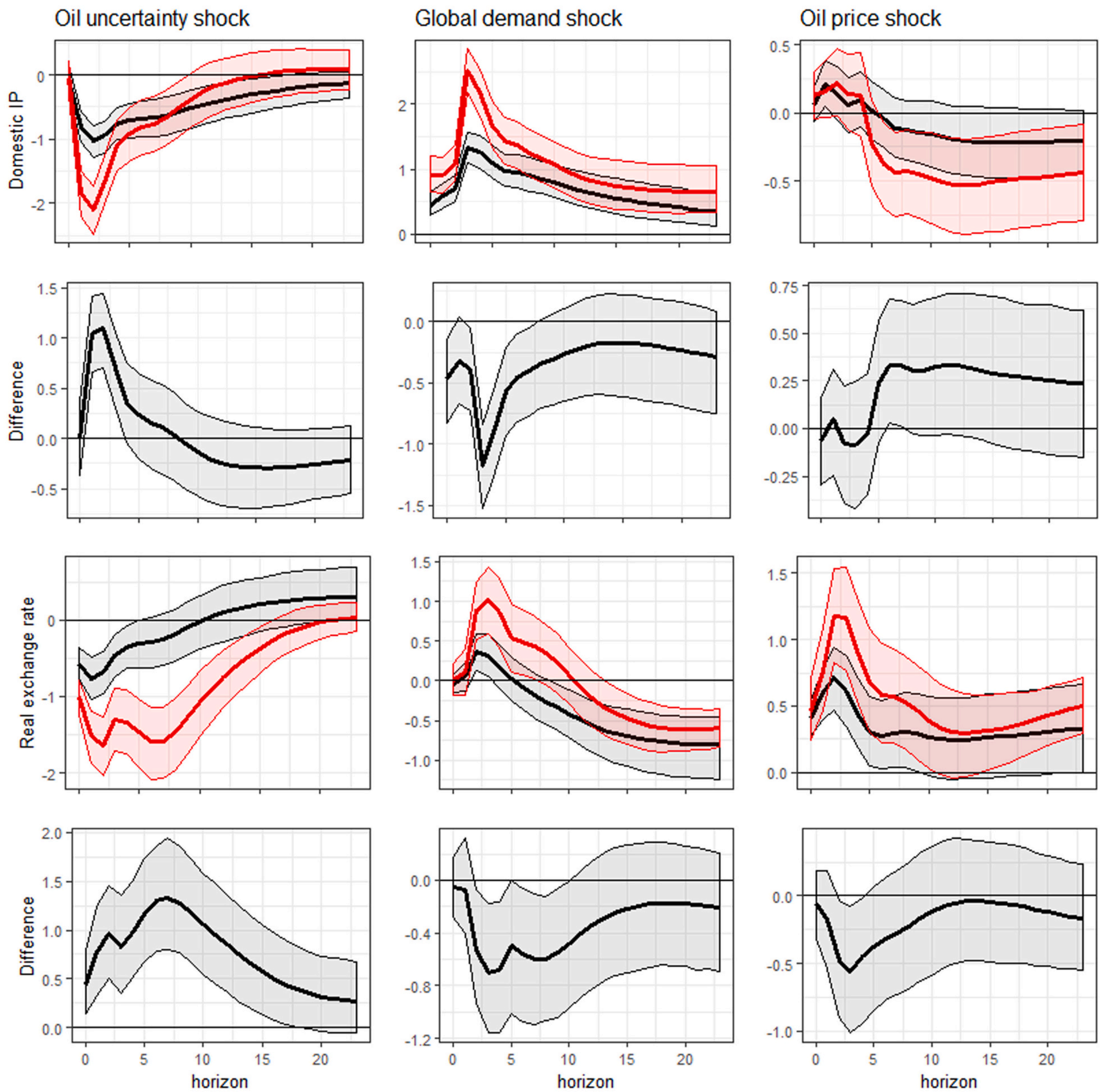


**Fig. 4.** Impulse response function of local variables to global shocks. Notes: Comparison of response of a country characterised by GDP per capita at 95% (grey line) and 25% (red line) level of the US level. The former value is an average of the two richest countries (Canada and Norway), whereas the latter is for the two poorest countries (Brazil and Colombia). The shaded areas represent the 90% bootstrapped confidence interval.

difference between the two responses, which allows us to assess whether the stage of economic development exerts a significant impact on the dynamic adjustment to shocks. For instance, the left panel of Fig. 4 clearly demonstrates that the oil uncertainty shock leads to a significantly higher decline in production and significantly stronger exchange rate depreciation in the poor economy compared to the rich one. On the contrary, the right panel of Fig. 4 indicates that the responses of both hypothetical economies to the oil price shock are not significantly different from each other. Finally, the middle panel of this figure illustrates how industrial production in developing countries is more susceptible to global demand conditions.

Overall, the results in this section allow us to assess that that oil price uncertainty shocks lead to a decline in economic activity and exchange rate depreciation in all oil-producing countries. However, the depreciation of developing countries' currencies is deeper and longer-lasting than in the rich countries. Next, we have not found significant evidence that the reaction of economies at different stages of economic development to the oil price shock is heterogenous. Finally, the forecast error variance decomposition analysis leads us to conclude that the contribution of oil market shocks to exchange rate volatility is inversely related to the stage of economic development.

## 6. Sensitivity analyses

In this section, we check if the findings described in the previous section are robust to changes in the design of our analysis. First, we change the proxy of oil price uncertainty from the OVX index to one based on the EGARCH(1,1) model. It can be noticed that in this case our results might be distorted due to the generated regressor problem described by Pagan (1984). This problem in small scale SVAR systems was addressed by applying a one-step estimation procedure by extending the model for GARCH in-Mean component (e.g. Elder, 2004).

Unfortunately, for the IPVAR system one-stage estimation has not been presented in the literature. For that reason we treat this analysis solely as a robustness check, bearing in mind that oil price uncertainty series calculated with one- and two-step procedures are quite similar (see Dossani and Elder, 2020). In the second robustness test we estimate the IPVAR model with two interaction variables, where the second variable is defined as the share of oil in exports. This will allow us to confirm that our main findings are valid, even if we control for other potential sources of heterogeneity across analysed countries. In the third sensitivity analysis, we just shorten the sample to exclude the impact of the volatile Covid-19 period from our analysis. This analysis is more comparable to earlier studies, which abstract from the impact of the pandemic on the dynamics of the oil market.

In each of the three above extensions, which we call SA1, SA2 and SA3, we replicate all the analyses that are described for the baseline settings in the previous section. For the sake of brevity, here we describe solely the reaction of the real exchange rate to the global shocks. We abstract from describing the reactions of global variables or domestic industrial production to disturbances. We neither present individual countries' impulse response functions. However, all these results are available upon request.

In Table 5 we present the result of forecast error variance decomposition of the real exchange rate in the three alternative scenarios. It shows that, in comparison to the baseline, the change in the uncertainty measure (SA1) or shortening the sample (SA3) is not changing the finding that the contribution of oil market shocks to exchange rate volatility is inversely related to the stage of economic development. However, the extension of the IPVAR model for the second interaction variable (SA2) indicates that oil exports intensity could also be considered as an important structural factor explaining the heterogenous impact of oil market shocks on exchange rate dynamics. Indeed, in the extended IPVAR model, the contribution of these shocks to the volatility of the Norwegian Krone, the currency of a country with a relatively high oil exports share, is now much higher than in the baseline or the other two developed countries. However, it can be noted that even in SA2 the contribution of oil market shocks to the forecast error variance of the Norwegian real exchange rate is lower than in developing countries, also those with relatively low oil exports intensity. This would suggest that the stage of economic development remains a significant structural factor explaining heterogeneity in the response to oil market shocks.

We can test the above hypothesis by comparing the reaction of the real exchange rate to global shocks of two hypothetical economies, rich and poor, which were defined in the previous section. In the SA2 model, which is extended for the second interaction variable, we assume that the oil net exports to GDP ratio in both hypothetical economies is the same and amounts to 2.5%, the value characteristic for Canada and Mexico. This comparison is presented in Fig. 5. It shows that all main results of the baseline analysis are very robust to the three changes in the settings of the analysis. First of all, the direction, scale, and persistence of the real exchange rate reaction to the three global shocks in both hypothetical economies are broadly the same across scenarios. Second, the differences in the reaction between the rich and poor countries are not sizeably affected by the changes in the model settings. For instance, the left panel of Fig. 5 shows that in all cases the depreciation of poor country currency is significantly deeper after the oil uncertainty shock compared to the reaction of rich country currency. Moreover, it can be noticed that the scale of the difference between these impulse-response functions is almost the same as in the baseline, apart from the SA3 case, in which the difference is somewhat less evident. As regards the response to the oil price shock, the right panel of Fig. 5 confirms that poor country currency appreciates more, but the difference is rather insignificant, apart from selected horizons in SA1. Finally, the middle panel of the figure shows that favourable global demand shock is (insignificantly) more supportive for developing countries' currencies. Overall, the sensitivity analyses confirm the main findings reported in the previous section.

**Table 5**
Contribution of oil market shocks to real exchange rate forecast error variance.

| Horizon | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| SA1: Alternative oil uncertainty measure | | | | | | | |
| 1 | 7.5 | 5.3 | 8.0 | 11.3 | 12.7 | 13.8 | 13.5 |
| 3 | 14.0 | 8.3 | 15.2 | 23.3 | 26.4 | 28.8 | 28.2 |
| 6 | 15.4 | 7.6 | 17.2 | 29.9 | 34.7 | 38.3 | 37.3 |
| 12 | 14.3 | 5.7 | 16.8 | 35.8 | 42.7 | 47.7 | 46.4 |
| 24 | 10.8 | 5.7 | 12.9 | 31.1 | 38.1 | 43.1 | 41.8 |
| SA2: Model with two interaction variables | | | | | | | |
| 1 | 9.3 | 12.4 | 6.4 | 23.8 | 18.8 | 24.8 | 16.6 |
| 3 | 15.7 | 18.3 | 13.8 | 33.7 | 31.9 | 37.3 | 32.8 |
| 6 | 17.8 | 22.3 | 14.5 | 40.7 | 37.7 | 44.2 | 37.5 |
| 12 | 17.7 | 28.2 | 11.6 | 53.1 | 47.6 | 56.1 | 46.2 |
| 24 | 15.3 | 29.4 | 8.2 | 55.6 | 48.2 | 56.8 | 46.0 |
| SA3: Non-covid sample | | | | | | | |
| 1 | 8.1 | 5.9 | 8.7 | 13.4 | 15.5 | 17.3 | 16.8 |
| 3 | 14.7 | 9.5 | 15.8 | 23.3 | 26.2 | 28.4 | 27.8 |
| 6 | 17.3 | 8.8 | 19.1 | 30.3 | 34.1 | 36.9 | 36.2 |
| 12 | 17.3 | 6.2 | 19.8 | 35.8 | 41.1 | 44.8 | 43.8 |
| 24 | 15.9 | 6.6 | 18.7 | 36.8 | 42.3 | 46.1 | 45.1 |

Notes: The table presents the combined share of oil price and oil uncertainty shocks to forecasts error variance.

## 7. Conclusions

The objective of this paper was to establish the reaction of oil-exporting countries to global oil market shocks and whether this reaction depends on the country-specific characteristics, e.g. the level of economic development. Building on the insights from the literature that explore the complex nature of the global oil market, we identified three shocks that disentangle the effects of conventional oil price level disturbances from those to oil price uncertainty and global demand. For seven oil-exporting countries (Brazil, Canada, Colombia, Mexico, Norway, Russia, and the United Kingdom), we have explained the dynamics of industrial production and the real exchange rate withing the Interacted Panel VAR framework adjusted for block exogeneity, in which we conditioned the responses of these variables to global shocks on the level of GDP per capita. Our approach made it possible to explain how differences in the stage of economic development lead to the heterogeneity in the responses of the economy to global oil market shocks in a coherent way.

There are two noteworthy implications of our findings. Given that responses to global shocks are more pronounced in emerging markets than in advanced economies, one can conjecture that the level of economic development may determine the strength of shock transmission. This result seems to be more noticeable in the case of the real exchange rate. The plausible implication may be that having mature and well-regulated financial markets can, at least to a certain extent, help mitigate the impact of global shocks. Second, policymakers should not be solely concerned about the effects oil price level shocks, as they can overlook even more important source of macroeconomic fluctuations, namely oil price uncertainty shocks. This is especially important in the case of oil-exporting countries at a low level of economic development. The reason is that institutional arrangements governing political processes in these countries are usually not fully developed, hence policymakers may be more prone to neglect developments in the oil market that go beyond the conventional oil price shocks and are relatively hard to explain in political debate.

## Credit Author statement

**Marek A. Dąbrowski**: Conceptualization, collecting and processing data, writing original draft, reviewing, and editing, formulation of

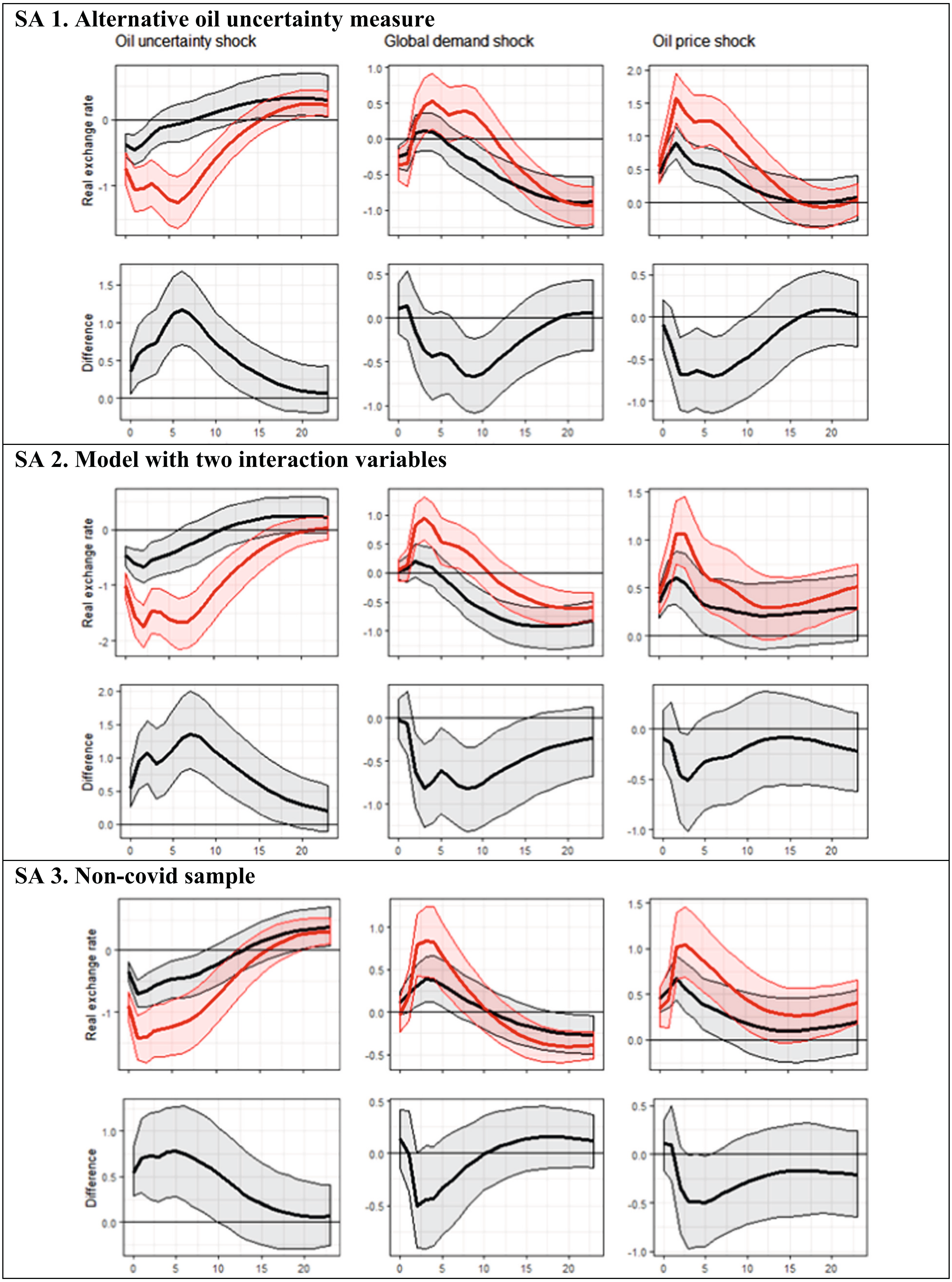


**Fig. 5.** Impulse response function of real exchange rate to global shocks. Notes: The figure presents the response of the real exchange rate to global shocks in countries characterised by GDP per capita at 95% (grey line) and 25% (red line) level of the US level. The shaded areas stand for the 90% bootstrapped confidence interval. In SA 2 oil export to GDP is set to 2.5%.

conclusions.

**Monika Papież**: Conceptualization, Data curation, Writing- Original draft preparation, Formal analysis, Visualization, Writing- Reviewing and Editing,

**Michał Rubaszek**: Formulation of econometric methodology, developing computer codes for IPVAR model; describing IPVAR methodology and simulation results; writing response to Reviewers.

**Sławomir Śmiech**: Conceptualization; Data curation, Formal analysis, Writing Original draft, Writing- Reviewing and Editing, Funding acquisition

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## Appendix A. Full results from sensitivity analyses (only for review process)

1. Sensitivity analysis: Alternative Oil Uncertainty Measure

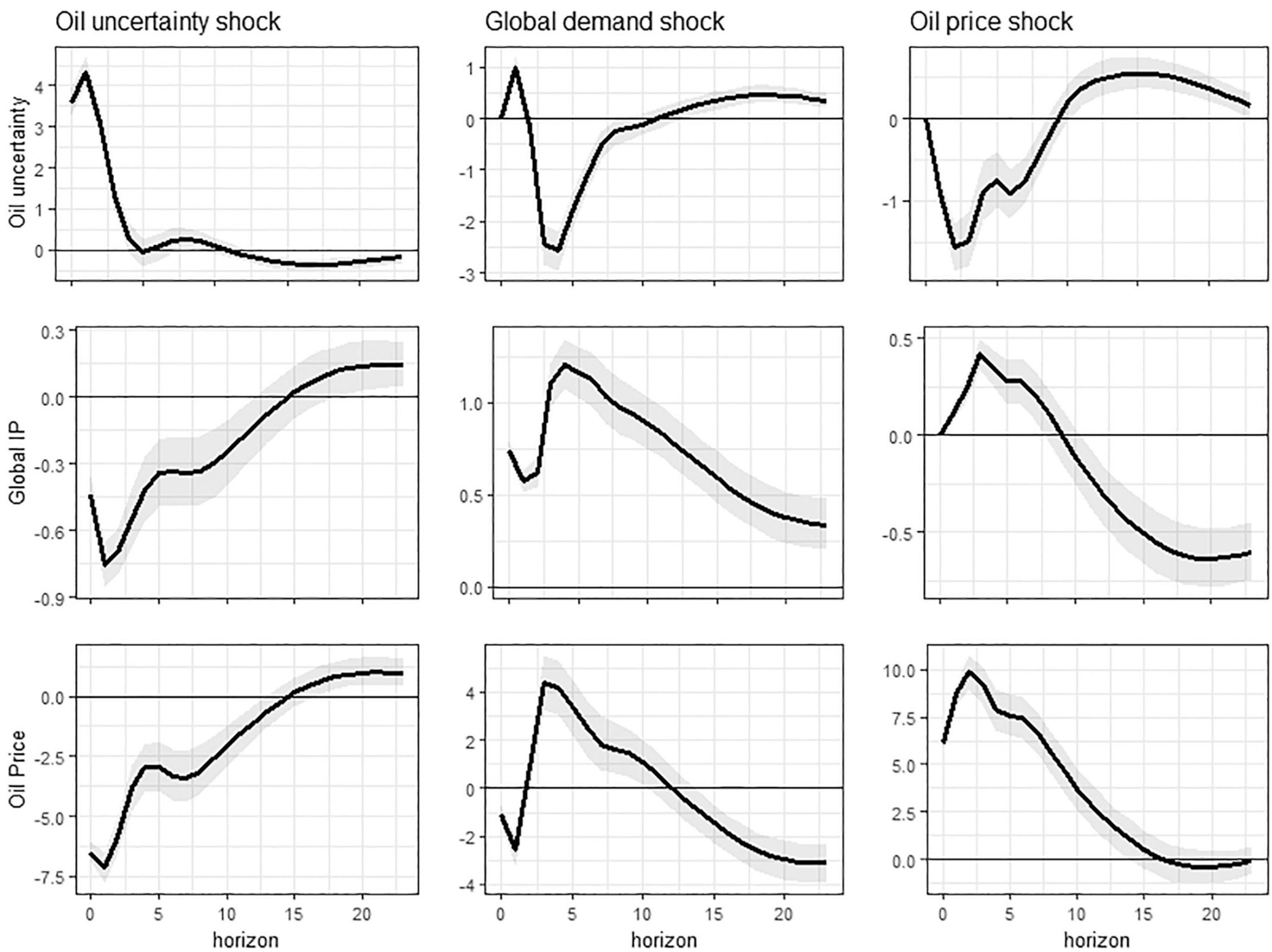


**Fig. A1.** IRF of global variables to global shocks. Alternative oil uncertainty measure. Notes: The solid lines represent the median response of global variables to global shocks. The shaded areas represent the 90% confidence interval.

**Table A1**
Contribution of oil market shocks to FEV. Alternative oil uncertainty measure.

| | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Industrial Production | | | | | | | |
| 1 | 13.1 | 5.2 | 14.7 | 25.4 | 29.2 | 32.1 | 31.3 |
| 3 | 30.7 | 17.6 | 33.2 | 47.6 | 52.3 | 55.6 | 54.7 |
| 6 | 24.3 | 17.8 | 25.5 | 32.6 | 35.0 | 36.7 | 36.2 |
| 12 | 20.7 | 18.2 | 21.3 | 24.8 | 26.0 | 27.0 | 26.7 |
| 24 | 18.0 | 16.1 | 18.4 | 21.8 | 23.1 | 24.2 | 23.9 |

(*continued on next page*)

**Table A1** (*continued*)

| | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Real exchange rate | | | | | | | |
| 1 | 7.5 | 5.3 | 8.0 | 11.3 | 12.7 | 13.8 | 13.5 |
| 3 | 14.0 | 8.3 | 15.2 | 23.3 | 26.4 | 28.8 | 28.2 |
| 6 | 15.4 | 7.6 | 17.2 | 29.9 | 34.7 | 38.3 | 37.3 |
| 12 | 14.3 | 5.7 | 16.8 | 35.8 | 42.7 | 47.7 | 46.4 |
| 24 | 10.8 | 5.7 | 12.9 | 31.1 | 38.1 | 43.1 | 41.8 |

Notes: The table presents the combined share of oil price and oil uncertainty shocks to forecasts error variance.

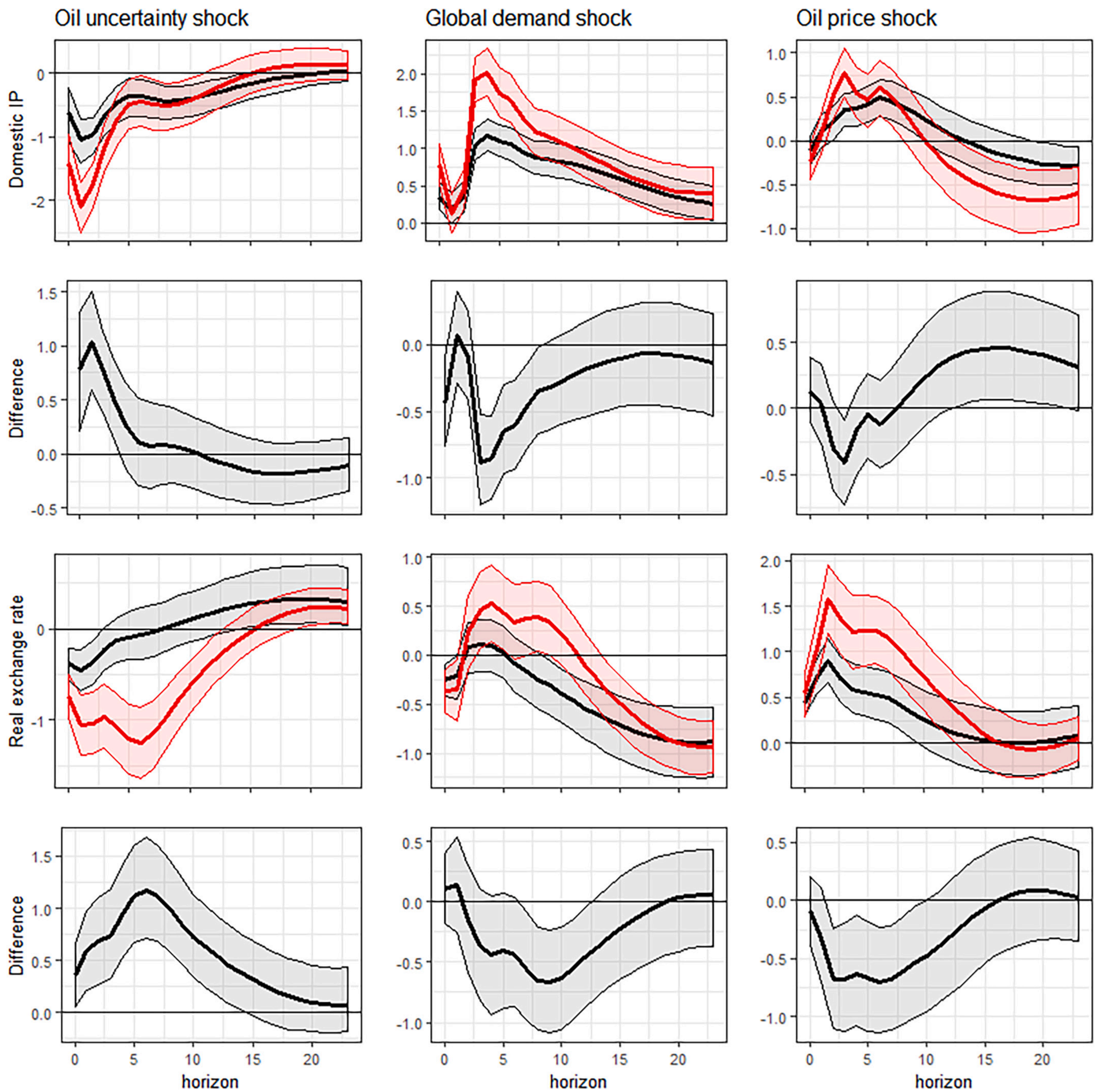


**Fig. A2.** IRF of local variables to global shocks and stage of development.
Alternative oil uncertainty measure. Notes: Comparison of response of a country characterised by GDP per capita at 95% (grey line) and 25% (red line) level of the US level. The former value is an average of the two richest countries (Canada and Norway), whereas the latter is for the two poorest countries (Brazil and Colombia). The shaded areas represent the 90% bootstrapped confidence interval.

2. Sensitivity analysis: Second interaction variable

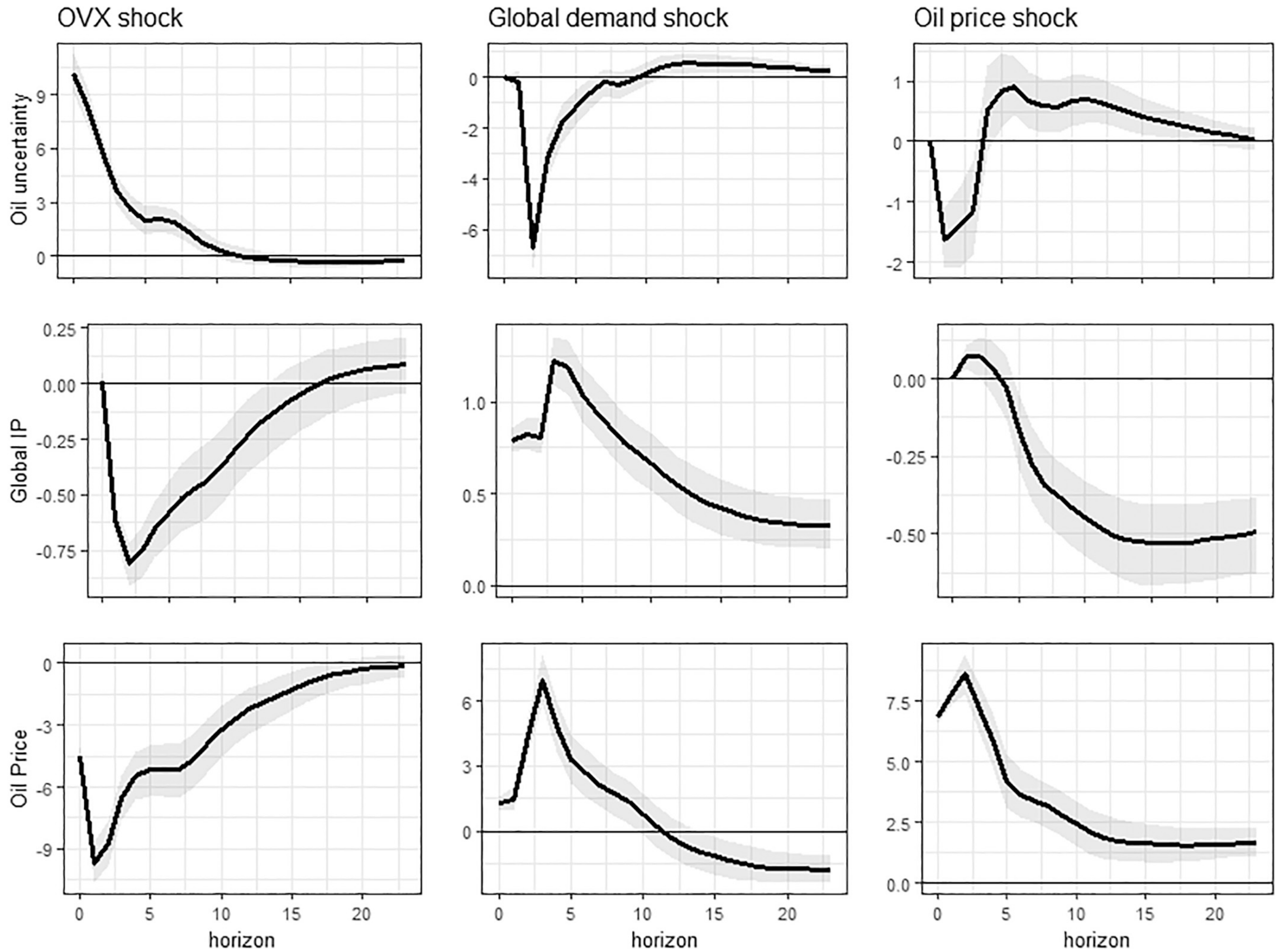


**Fig. A3.** IRF of global variables to global shocks. Second interaction variable. Notes: The solid lines represent the median response of global variables to global shocks. The shaded areas represent the 90% confidence interval.

**Table A2**
Contribution of oil market shocks to FEV. Second interaction variable.

| | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Industrial Production | | | | | | | |
| 1 | 0.1 | 0.7 | 0.1 | 1.0 | 0.3 | 0.7 | 0.3 |
| 3 | 29.6 | 4.7 | 38.7 | 26.2 | 43.8 | 40.1 | 49.9 |
| 6 | 24.6 | 12.8 | 27.6 | 25.0 | 31.5 | 30.4 | 33.6 |
| 12 | 21.8 | 17.2 | 23.6 | 23.1 | 26.7 | 26.0 | 28.3 |
| 24 | 18.9 | 19.8 | 20.5 | 22.4 | 23.2 | 24.5 | 24.8 |
| Real exchange rate | | | | | | | |
| 1 | 9.3 | 12.4 | 6.4 | 23.8 | 18.8 | 24.8 | 16.6 |
| 3 | 15.7 | 18.3 | 13.8 | 33.7 | 31.9 | 37.3 | 32.8 |
| 6 | 17.8 | 22.3 | 14.5 | 40.7 | 37.7 | 44.2 | 37.5 |
| 12 | 17.7 | 28.2 | 11.6 | 53.1 | 47.6 | 56.1 | 46.2 |
| 24 | 15.3 | 29.4 | 8.2 | 55.6 | 48.2 | 56.8 | 46.0 |

Notes: The table presents the combined share of oil price and oil uncertainty shocks to forecasts error variance.

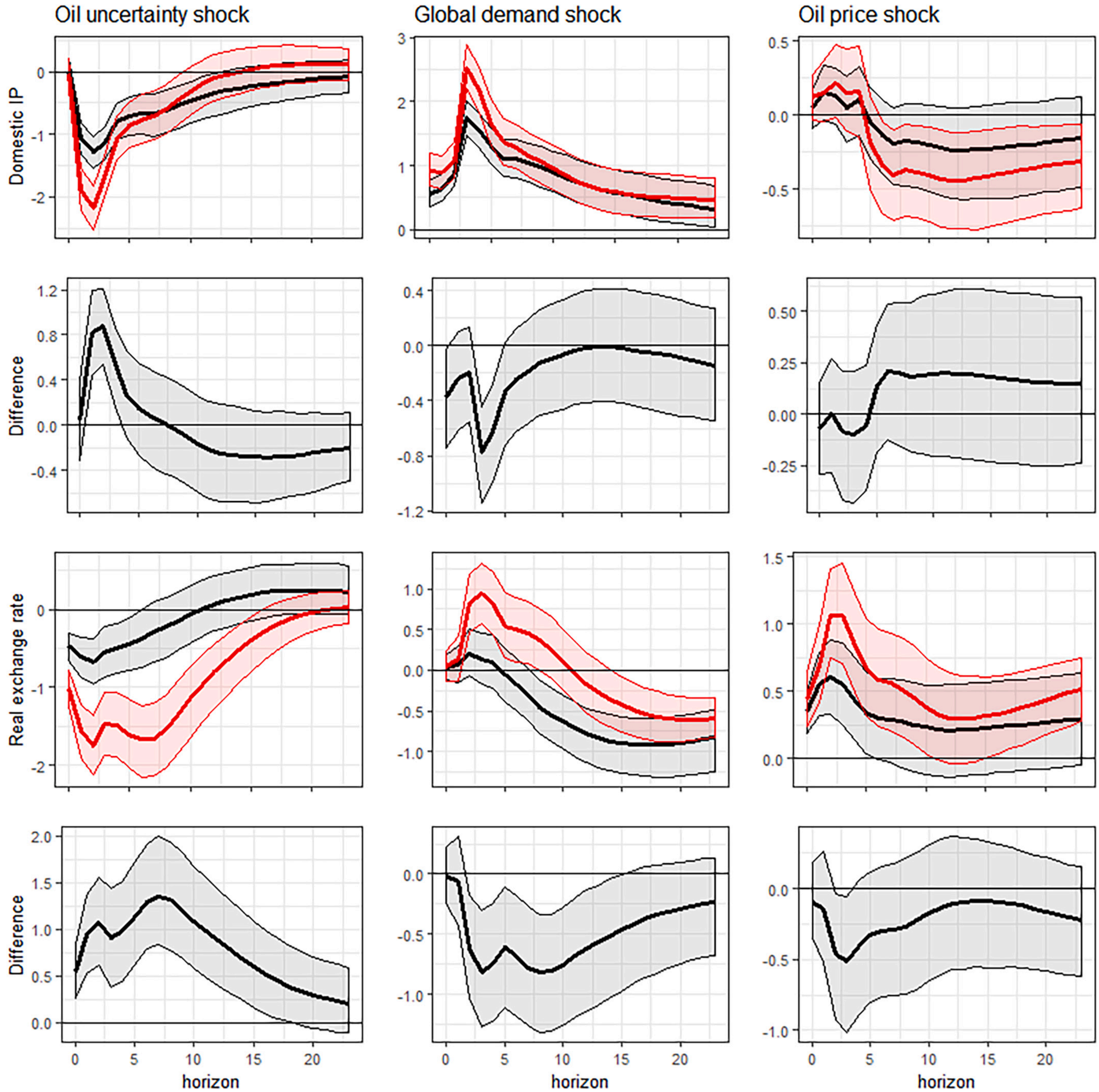


**Fig. A4.** IRF of local variables to global shocks and stage of development. Second interaction variable. Notes: Comparison of response of a country characterised by GDP per capita at 95% (grey line) and 25% (red line) level of the US level. The former value is an average of the two richest countries (Canada and Norway), whereas the latter is for the two poorest countries (Brazil and Colombia). In both cases oil export to GDP is set to 2.5%. The shaded areas represent the 90% bootstrapped confidence interval.

3. Sensitivity analysis: Non-covid sample

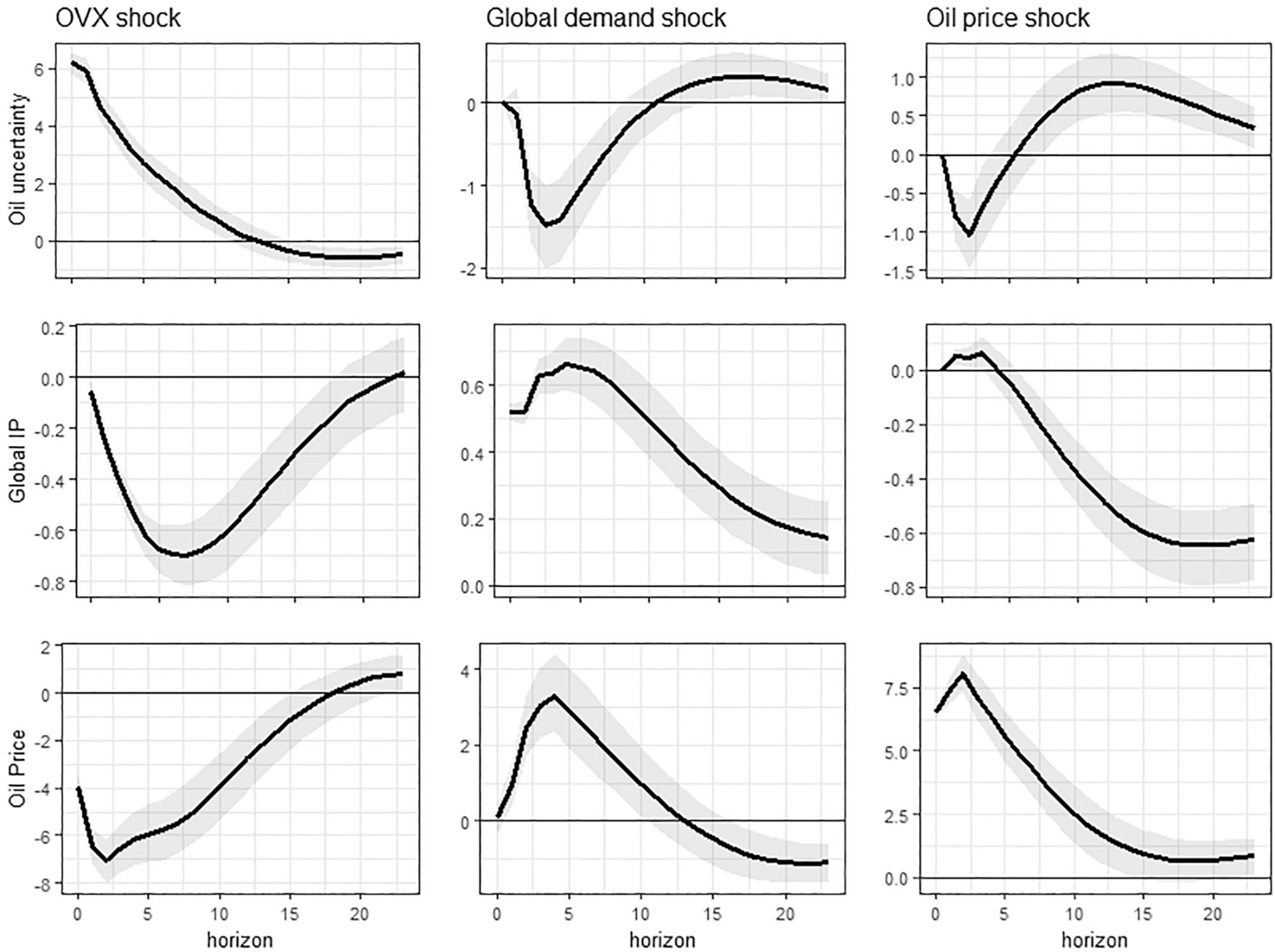


**Fig. A5.** IRF of global variables to global shocks. Non-covid sample. Notes: The solid lines represent the median response of global variables to global shocks. The shaded areas represent the 90% confidence interval.

**Table A3**
Contribution of oil market shocks to FEV. Non-covid sample.

| | CAN | NOR | GBR | RUS | MEX | COL | BRA |
|---|---|---|---|---|---|---|---|
| Industrial Production | | | | | | | |
| 1 | 0.1 | 0.0 | 0.1 | 0.4 | 0.5 | 0.7 | 0.6 |
| 3 | 2.6 | 1.9 | 2.8 | 5.9 | 7.4 | 8.8 | 8.4 |
| 6 | 11.5 | 9.5 | 12.0 | 16.2 | 18.1 | 19.6 | 19.2 |
| 12 | 26.4 | 29.7 | 26.1 | 25.4 | 25.7 | 26.1 | 26.0 |
| 24 | 34.3 | 40.5 | 33.5 | 30.5 | 30.3 | 30.3 | 30.3 |
| Real exchange rate | | | | | | | |
| 1 | 8.1 | 5.9 | 8.7 | 13.4 | 15.5 | 17.3 | 16.8 |
| 3 | 14.7 | 9.5 | 15.8 | 23.3 | 26.2 | 28.4 | 27.8 |
| 6 | 17.3 | 8.8 | 19.1 | 30.3 | 34.1 | 36.9 | 36.2 |
| 12 | 17.3 | 6.2 | 19.8 | 35.8 | 41.1 | 44.8 | 43.8 |
| 24 | 15.9 | 6.6 | 18.7 | 36.8 | 42.3 | 46.1 | 45.1 |

Notes: The table presents the combined share of oil price and oil uncertainty shocks to forecasts error variance.

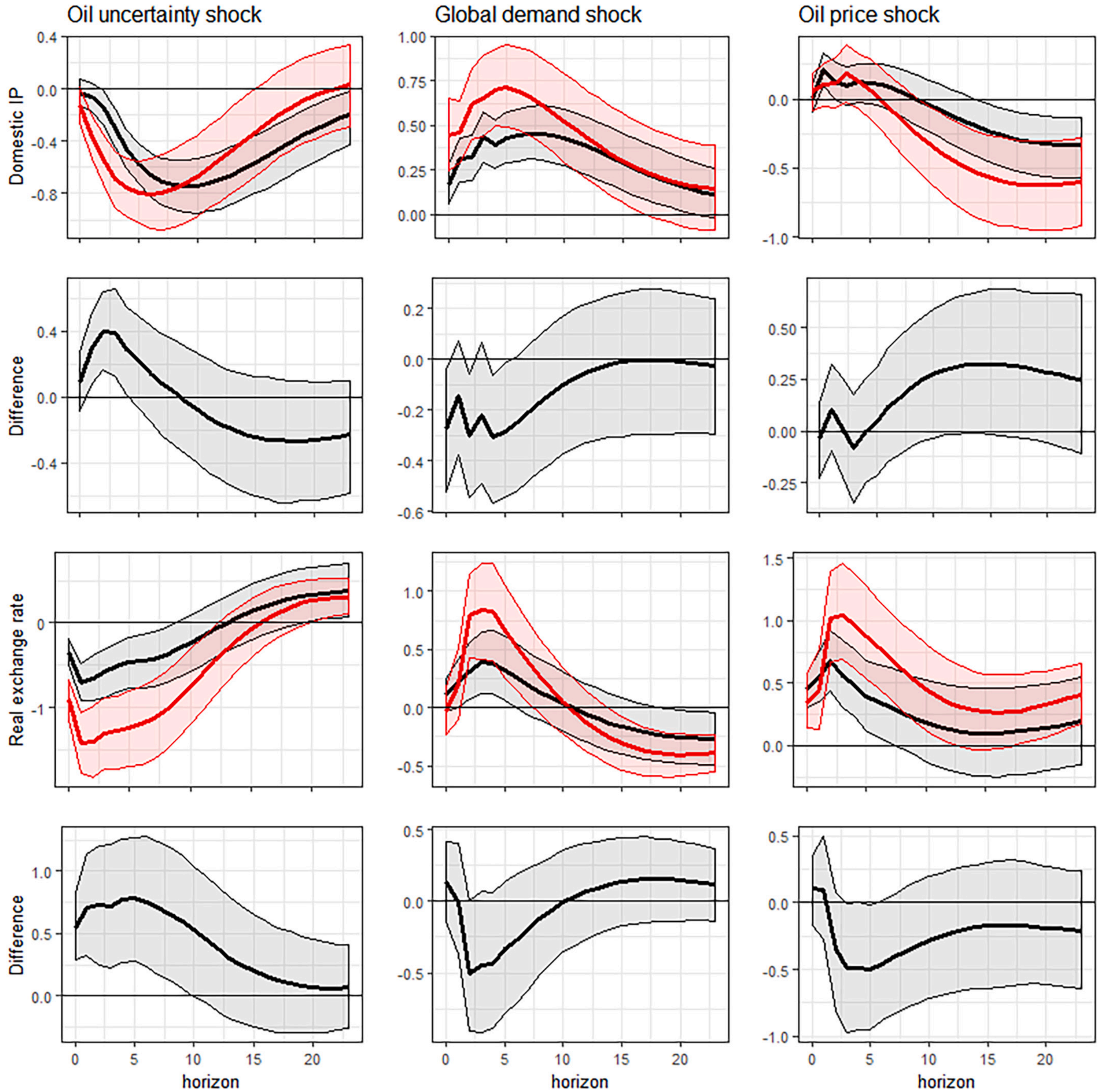


**Fig. A6.** IRF of local variables to global shocks and stage of development. Non-covid sample. Notes: Comparison of response of a country characterised by GDP per capita at 95% (grey line) and 25% (red line) level of the US level. The former value is an average of the two richest countries (Canada and Norway), whereas the latter is for the two poorest countries (Brazil and Colombia). The shaded areas represent the 90% bootstrapped confidence interval.

## Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2022.106017.

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