Energy Economics 128 (2023) 107156

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Energy price shocks, exchange rates and inflation nexus

Simona Bigerna *

Department of Economics, Università degli Studi di Perugia, via A. Pascoli, 20, 06123 Perugia, Italy

A R T I C L E I N F O

Keywords:
Oil price
Exchange rate
Inflation
VARX
Volatility spillover

A B S T R A C T

Energy price shocks, exchange rates and inflation have challenged macroeconomics stability in the recent past, during the Covid-19 crisis and the following high growth recovery post Covid. The joint relations among these three main macro-variables: exchange rate, consumer price and oil prices is modeled in this paper, in the periods of pre-Covid and of supply recovery after the Covid-19 lockdown. The estimation of an empirical VARX model on monthly data from Jan 2010 to Dec 2021 for the main 15 countries of the G20 shows asymmetric effects, offers a detailed contagion analysis, conducted with the methodology a la Pesaran and Pick (2007) to identify periods of high volatility, and presents a spillover analysis a la Diebold and Yılmaz (2014), used to measure the connectedness of the three main variables.The main innovative contributions are: i) the analysis of the country specific oil portfolio; ii) the general impulse response spillover, to ascertain the intensity and direction of volatility connectedness; iii) the disentangling of the effects on the exchange rate and price stability stemming from oil prices shocks. The empirical results show that: i) significant effects differences depend on the specific oil price considered for each country; ii) oil price changes impacts depend on the direction and period of the shock; iii) asymmetric contagion effects are relevant only for some oil importing countries and for exchange rate and inflation. Finally, based on the spillover connectedness, some policy implications are discussed.

1. Introduction

The nexus between energy price shocks, exchange rates and inflation in macroeconomics stability has been challenged in the recent past due to two main events, the sharp downturn of the economic activity in mid-2020 because of the lockdown enacted to curb the spread of the Covid 19 pandemic and the high growth recovery post Covid with a sustained price increase started in September 2021.

In the literature, there are several analyses that have considered pairs of nexuses: oil and the exchange rate, oil and inflation, oil and stock markets, oil and gold and exchange rates; some focus on correlation, some focus on contagion, some focus on spillover analysis across markets. Surprisingly, in the period of extreme shocks – (in 2020 there has been a dramatic economic slowdown during the Covid 19 lockdown and at the end of 2021 there has been a sustained price increase due to bottlenecks in the global supply chain) – there has not been a comprehensive analysis of the three main relevant variables, oil prices, exchange rate, inflation, which are the main variables impacting consumers and firms' economic life and activity, as well as forming the core of the policy makers' attention. It suffices to recall that the Annual Report of the Federal Reserve System at the end of 2021 (FED, 2021) was still reporting that, with the actual annual inflation up to 5.8% in December 2021, *"inflation expectations […] appear broadly consistent with the FOMC's longer-run inflation objective of 2%, […] and the FOMC has continued to keep the target range for the federal funds rate at 0 to 1/4 percent, for the period Mar 2020 – Dec 2021"*.

Even if recently some researchers have analyzed these three relevant variables (see among others Garzon and Hierro (2022), Philips et al., 2022, Ding et al., 2023), this paper tries to fill this gap focusing the research on disentangling the effects on the exchange rate and price stability coming from the shocks of the oil prices, in the periods before and after Covid-19 lockdown. Compared with the existing literature, the original contribution of this paper is three-fold.

First, the analysis is conducted with a Vector Auto Regression (VAR) estimation of all three main relevant variables: oil prices, exchange rate, inflation. Monthly data are used from Jan 2010 to Dec 2021 for the main 15 countries by the G20. We want to stress that while most of the extant literature: i) has focused on binary nexuses (either oil price and exchange rate or oil price and inflation); ii) has only analyzed a small group of countries, this is the first work to comprehend an analysis for most of the G20 main important countries of all three main variables.

Second, this paper considers specific oil prices constructed for each

* Corresponding author.
E-mail address: simona.bigerna@unipg.it.

https://doi.org/10.1016/j.eneco.2023.107156
Received 31 December 2022; Received in revised form 7 October 2023; Accepted 27 October 2023
Available online 4 November 2023

country. This is a novel view, which aims at identifying more precisely the quantitative impact of the specific imported (or exported) oil price on the macroeconomic variables, considering a portfolio of main suppliers to each importing country and of the main customers of each exporting country. This novel approach is based on the notion of "oil suppliers' portfolio" that has been initially developed in Bigerna et al. (2021). The main rational of this approach is that in this way the analysis includes a richer understanding of the differential impact of oil prices, inflation and exchange rates in each country. In other words, what really affects domestic prices and exchange rates is the dynamics of the specific characteristics of types of crude oil and of refinery technologies used in each country, rather than the reference to an international index, such as Brent and/or WTI. This is a potentially relevant contribution to the policy maker because the exchange rate is affected by real currency flows, as well as the price pass-through is determined by actual prices, and not by reference indexes. The novel approach of this paper is that potential asymmetry of positive and negative oil shocks is assessed with a new method, implemented as a variant of the Nasir and Leung (2021) method. In addition, the contagion analysis methodology a la Pesaran and Pick (2007) is used to identify periods of high volatility, rather than defining predetermined exogenous breakpoint. It is crucial to underline that the empirical method used distinguishes between interdependence and contagion and to differentiate the asymmetric effects, according to the direction of change.

Third, the spillover analysis method (Diebold and Yılmaz, 2014) is implemented, to measure the connectedness among the three main relevant variables, considering both orthogonal and general impulse response analysis. This latter is possibly the main innovative contribution of this paper, because it is possible to ascertain in a comprehensive fashion both the intensity and the direction of volatility spillovers among the variables considered. This is crucial for policy makers.

The paper is organized as follows. Section 2 presents a review of the literature. Section 3 presents the theoretical model and the data. The estimation method is presented in Section 4. The empirical results are reported in Section 5 and the discussion of the results is in Section 6. Section 7 concludes, and an appendix provides some technical details.

2. Related literature

The relationship between foreign exchange rates, energy prices, and consumer price inflation is an interesting issue of investigation according to the economic theory, as recently partially highlighted by Garzon and Hierro (2022), Philips et al. (2022), Ding et al. (2023). This relationship is analyzed focusing on the dampening role of the exchange rate in oil price pass-through in the Euro area (Garzon and Hierro, 2022), while in Philips et al. (2022) the exchange rate is viewed as a critical determinant of to the cyclicality of oil prices and stock returns in specific periods, but inflation is insignificant (even if this result is country dependent). Finally, Ding et al. (2023) find that the covariance between exchange rates and oil prices explains and predicts inflation. An interesting policy implication is that the exchange rate can be used to stabilize inflation, reducing the covariance between the exchange rate and oil price, in the turmoil periods and in the emerging countries.

The consensus is that consumer price inflation in an open economy is expected to be directly affected by changes in the cost of imported goods in terms of domestic currency due to foreign exchange rate fluctuations or energy prices, and these relationships are highly affected by the economic context.

Since the pioneering Goldberg and Knetter (1997), it is understood that a change in exchange rate affects the local currency import prices, resulting in a partial effect on inflation. Coherently, given that the US dollar (USD) and the euro are the main trading currencies for international trade, the Fisher effect suggests that any significant depreciation of other domestic currencies could result in higher inflation, determining the pass-through effect from foreign exchange rates to consumer price inflation (Choudri and Hakura, 2001, 2006). In this line of research, several scholars have investigated these relationships worldwide and Levich (1985) provided one of the first overview of empirical results. Recently, Beckmann et al. (2020) provide an exhaustive analysis of the theoretical transmission mechanisms between energy prices and foreign exchange rates, underlining the central role of inflation in affecting both nominal and real energy prices and both nominal and real foreign exchange rates. They also stress the importance of other determinants (such as GDP, stock prices, uncertainty) that make it difficult to predict both foreign exchange rates and energy prices. Balcilar and Usman (2021) investigated for the BRICS countries the exchange rate and oil price pass-through on inflation (e.g., second stage exchange rate pass-through). Their analysis highlights the appreciable fluctuations of the exchange rate and oil price even if no clear-cut evidence of trends among the variables arises. Focusing on Turkey, Küçükefe (2020) analyze this relationship using a cointegration model and find that the consumer price index is directly affected by the exchange rate changes, while the reaction to oil price shocks is less intense in size and time. Oloko et al. (2021), using the fractional cointegration vector autoregressive approach on top oil importing and exporting countries find that the inflation persistence in both oil exporters and importers is not increased by oil price shocks, thus rendering important suggestions for the monetary policy responses to oil shocks. Focusing on emerging African economies, Ahmed and Huo (2020) found significant return and volatility interactions of oil return, exchange rates and stock markets. The same relationship has been investigated referring to selected twelve oil exporting economies by Kumeka et al. (2022) to assess the Covid-19 effect, finding that variables were affected by the dynamics in own shocks. In any case, the nexus among these three variables has attracted interest since the first oil crisis. Among others, Black and Benzing (1991) applied Stein's real-balance inflation equation (Stein, 1982) explaining the potential for both foreign exchange rates and energy price effects. They find that a 10% depreciation of the foreign exchange rates increases by 0,56% and 1,4% the implicit GNP deflator over one year and three years, respectively. Despite the great development of renewables worldwide, oil is still the main source of energy input for many industries. Thus, oil price is one of the main factors determining consumer prices and consequently, there is a recent literature on the relation between energy price shocks and macro variables (Nasir and Leung, 2021, Golis et al., 2022, Hashmi et al., 2021). Particularly, Lin and Su (2020) using the ensemble empirical mode decomposition on BRICS countries show that: (i) there are different responses to oil price shocks in net oil importers and exporters; (ii) exchange rates show any significant response to oil price shocks only at the high frequency data.

Focusing on the linkage between oil price shocks and inflation, Garzon and Hierro (2021) show (using a two-stage approach) that differences in inflation regimes are relevant to explain the oil shock transmission, on both demand and supply side. They show that positive shocks a have a higher impact in high inflation regimes. China is one of the most analyzed countries (see among others Zhao et al., 2016, Jia et al., 2021) given that it is the world's largest oil consumer after the USA. Recently, Sun et al. (2022) have employed the MS-VAR technique to see whether the relationship between China's exchange rate, the domestic price of crude oil, and the international price of crude oil have changed following the introduction of the financial instrument of China's crude oil future. Among various results, it emerges that the price of Chinese oil is strongly influenced by the international crude oil market. A previous VAR analysis of oil prices of main suppliers in China and Japan has measured the total and bilateral volatility spillovers of the portfolio risk associated with the composition of the main oil suppliers for a group of importing countries (Bigerna et al., 2021). In the same context, Caporin et al. (2021) construct asymmetric spillover measure for the commodity market, finding that, among five commodities analyzed, volatility connectedness is a long-run phenomenon and that that the good volatility is determined by the bad volatility connectedness.

Summarizing, the main findings of the extant literature show that

Table 1
Main oil partners of the countries.

Country	Main oil partners	
Australia (AU)	Indonesia (ID)	Malaysia (MY)
Brazil (BR)	Saudi Arabia	United States
Canada (CA)	Saudi Arabia	United States
China (CN)	Saudi Arabia	Russia
France (FR)	Saudi Arabia	Russia
Germany (GE)	Russia	Norway (NO)
India (IN)	Saudi Arabia	Iraq (IQ)
Italy (IT)	Russia	Azerbaijan (AZ)
Japan (JP)	Saudi Arabia	United Arab Emirates (AE)
Korea (KR)	Saudi Arabia	United Arab Emirates
Russia (RU)	China	Netherlands (NL)
Saudi Arabia (SA)	China	Japan
South Africa (ZA)	Angola (AN)	Nigeria (NG)
United Kingdom (UK)	Norway (NO)	Nigeria
United States (US)	Canada	Korea

energy prices affect exchange rates and positive oil shocks affect differently the inflation rates. However, the existing contributions seem to focus on some details, but neglecting others. For instance, there is an analysis of financial and oil for an important country like China, but there is no simultaneous treatment of asymmetry and contagion, nor there is a systematic analysis for both oil importing and exporting countries. Overall, while recent literature confirms that understanding the relationship between CPI, foreign exchange rates and oil prices is still an open question, this paper attempts to provide a more general empirical analysis which could prove useful for the policymakers.

3. Model and data

The proposed model accounts for the theoretical relationship among oil prices, exchange rates, inflation, and other common factors. According to Beckmann et al. (2020) it is important to identify various channels of relationships: a term of trade channel links oil prices to real exchange rates via domestic prices, but also a wealth channel links nominal exchange rate to oil price, especially in oil exporting countries. A portfolio effect is also considered in the proposed model, constructing a portfolio of main customers or oil exporting countries and a portfolio of main suppliers for oil importing countries. The model also considers a slightly more general pass-through effect than the classic pass-through of exchange rate on inflation (Nasir and Vo, 2020). In this paper, specific oil shocks stemming from the specific suppliers of a country interact with exchange rate movements and inflation patterns, modeling both asymmetric effect and contagion effects. In addition, again following Beckmann et al. (2020), it is important to consider other common exogenous factors that affect the oil price, exchange rate, inflation nexus, such as economic activity, monetary policy, economic structure, trade structure, expectations, and uncertainty. In line with these considerations, the proposed model is a VAR-X estimated for each country with four endogenous variables: the two main oil prices, real exchange rate, inflation and a set of nine exogenous variables, that are all proxies of the common factors mentioned above: (i) and (ii) asymmetric negative and positive oil price shocks; (iii) negative exchange rate changes (depreciation); (iv) and (v) asymmetric negative and positive contagion effects, which jointly capture the essence of short term wealth effect and expectation effects; (vi) and (vii) industrial production and unemployment rate, which proxy the level of economic activity; (viii) policy based interest rates which capture the stance of the monetary policy; (ix) shares of imports from emerging countries, which proxy the trade structure.

The analysis is based on a unique data set of monthly data, January 2010 – December 2021 with nonlinear asymmetric VAR estimation, contagion identification and spillover analysis. The data set is for the major 15 countries of G20: Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Saudi Arabia, South Africa, Russia, UK, USA.

For each country data are collected for exchange rates, inflation, and a portfolio of oil import prices, charged to the oil importers by the major world oil exporters (like: Saudi Arabia, Russia, Iran, Iraq, Kuwait, Norway, Nigeria, United States) and a portfolio of oil export prices charged to the major customer for the three oil exporters in the sample Russia, Saudi Arabia, and the USA.

The exchange rates are taken from the public data bank (Darvas, 2021) and are computed as Real Effective Exchange Rates (REER), at the monthly frequency.[1]

The consumer price indices (CPI) are taken from the IMF (2022) and World Bank (WB) (2022) and are at the monthly frequency, except Australia, which publishes data only at the quarterly frequency, for which interpolation has been implemented (Australia started to produce a monthly price index only in 2022). The oil prices are taken as unit values of the product 2709 (SITC 4 classification), as reported by the TRADECOM databank. (UN, 2022a). All data are in dollar terms and in quantities, different from different countries: kilograms, tons, liters, barrels.

All the unit values were computed dividing dollar values by the quantity, converted into tons. For each importing country, we consider the two most important suppliers in terms of long-term shares. For each exporting country, the two most important customers were considered. The series of industrial production, unemployment rate, policy-based interest rates, shares of imports from emerging countries are taken from the IFS data base of IMF (2022), with some missing data in the most recent months for some countries taken from national sources, as done in the IMF database.

The list of 15 major G20 countries considered is reported in Table 1, together with the two main oil partners, with an identifying label used in the rest of the paper (for instance: Australia is AU, see footnote 4).

Overall, the data considered are four variables for each country: two specific oil prices (as listed in Table 1), exchange rate, inflation. The summary statistics of the variables are reported in Table 2. Each variable is identified with CPI for inflation, XR for exchange rate whit a suffix indicating the country (for instance, CPIAU is inflation, Australia), and the country label for the oil price, with a suffix indicating the partner (for instance: AU_MY is oil price of imports of Australia from Malaysia).

Table 2 reports mean, variance 1st and 3rd quartile showing variation in the inflation rates between 1% and 7% a month, in the exchange rate levels between 4.4 and 4.8, and in oil prices of the 1st and the 3rd quartile between 360 and 850 USD/ton. A preliminary analysis of cointegration confirms that validity of the empirical strategy, as (most of) the level variables are I(1). This is shown by augmented Dickey and Fuller (1979) and Phillips and Perron (1988) tests for the level variables. In addition, the four variables (two oil prices, CPI and XR) are cointegrated for each country, as shown and by the Engle and Granger (1987) tests, as reported in detail in the Appendix.

4. Method

The VAR with exogenous determinants (VAR-X) model, for each country, is of the general form:

$$Y_t = \Sigma_{j=(1..p)}\, \Phi_j\, Y_{t-j} + \Sigma_{k=(1..q)} \Psi_j\, X_{t-k} + U_t \tag{1}$$

Where Y_t is a vector with elements $\{y_1, y_2, y_3, y_4\}$ denoting: y_1 = first oil price; y_2 = second oil price; y_3 = XR; y_4 = CPI of the country and X_t is

[1] The REER is a useful measure of a country's currency against a basket of the country's trading partners, adjusted for the domestic cost. Change in the REER is an indicator of changes in the equilibrium value of a currency, in cost competitiveness of the economy, in trade flows. Operationally, REER is computed as a geometric weighted average of the bilateral exchange rates of a country vs. trading partners, where weights reflect the partners importance, adjusted by the ratio of domestic to foreign prices.

Table 2
Summary statistics.

Variable	Mean	Std Dev	1st Qrt	3rd Qrt
CPIAU	2.19	0.81	1.50	2.97
CPIBR	6.28	2.23	4.76	8.06
CPICA	1.88	0.98	1.15	2.31
CPICN	2.44	1.53	1.52	3.02
CPIFR	1.14	0.80	0.44	1.74
CPIGE	1.46	1.06	0.80	1.98
CPIIN	7.23	3.04	4.87	9.65
CPIIT	1.27	1.19	0.19	2.20
CPIJP	0.16	0.94	−0.42	0.53
CPIKR	1.91	1.18	0.95	2.68
CPIRU	7.14	3.54	4.91	8.14
CPISA	3.02	2.26	1.20	5.25
CPIZA	4.99	1.10	4.23	5.96
CPIUK	2.10	1.14	1.01	2.76
CPIUS	2.08	1.45	1.18	2.62
XRAU	4.68	0.07	4.62	4.75
XRBR	4.56	0.20	4.44	4.72
XRCA	4.49	0.09	4.41	4.58
XRCN	4.85	0.10	4.77	4.93
XRFR	4.53	0.03	4.51	4.55
XRGE	4.53	0.02	4.51	4.54
XRIN	4.76	0.07	4.70	4.83
XRIT	4.55	0.02	4.54	4.57
XRJP	4.65	0.14	4.54	4.81
XRKR	4.48	0.06	4.42	4.53
XRRU	4.54	0.14	4.40	4.67
XRSA	4.82	0.08	4.74	4.89
XRZA	4.53	0.12	4.45	4.63
XRUK	4.45	0.05	4.41	4.46
XRUS	4.70	0.10	4.60	4.78
AU_MY	590.62	196.01	412.08	810.98
AU_ID	575.17	190.98	410.09	787.45
CA_US	516.70	163.01	370.53	676.02
CA_SA	536.03	195.48	367.67	733.48
BR_US	740.10	257.11	518.38	936.38
BR_SA	552.56	194.32	367.92	771.09
CN_SA	546.81	192.92	382.33	755.10
CN_RU	560.32	202.86	385.74	776.67
FR_SA	559.23	185.31	397.52	761.47
FR_RU	559.64	189.18	395.00	763.21
GE_RU	544.78	191.98	387.22	753.82
GE_NO	588.64	197.15	415.32	793.30
IN_IQ	524.02	194.21	358.32	734.06
IN_SA	555.73	193.35	393.58	768.63
IT_RU	556.79	191.51	387.67	766.39
IT_AZ	593.88	198.74	423.98	802.49
JP_AE	587.92	198.06	419.11	817.53
JP_SA	574.42	196.83	404.32	795.99
KR_SA	564.77	191.27	395.92	781.30
KR_AE	588.51	200.03	414.86	821.83
RU_CN	562.24	196.80	391.95	794.76
RU_NL	531.57	193.78	364.63	746.67
SA_CN	546.81	192.92	382.33	755.10
SA_JP	574.42	196.83	404.32	795.99
ZA_NG	587.53	201.18	396.91	814.77
ZA_AN	556.64	205.19	364.08	771.04
UK_NO	605.36	198.47	415.20	814.12
UK_NG	590.14	203.02	426.00	813.58
US_CA	458.05	148.16	316.84	595.90

a matrix of exogenous variables of the country, with elements $\{x_1, x_2, x_3, x_4, x_5\}$ to be discussed below, assuming lag q = 0. The lag = p is later determined by the Akaike criterion. The order in eq. (1) is the maintained hypothesis for the Cholesky decomposition of the impulse response (IR) and the Forecast Error Variance Decomposition (FEVD). The first oil price is the relatively more important in the import (export) portfolio of the country, then the second, then the exchange rate is the macro variable first affected by the oil price and last the domestic inflation rate. In addition, the generalized IR and FEVD are computed, thus relaxing the maintained ordering hypothesis to be used later for the volatility spillover analysis. The exogenous vector X_{jt} with elements $\{x_1 - x_9\}$ includes, for each country j, the asymmetric changes of the oil price (x_1, x_2), the negative change (devaluation) of the exchange rate (x_3), the *asymmetric contagion effects* (x_4, x_5), the policy interest rate (x_6), the unemployment rate (x_7), the industrial production index (x_8), the share of imports from emerging countries (x_9). Precisely, the variables (x_1, x_2) are both the negative change and positive change of oil price (eq. 2), and the variable (x_3) is the negative change of the exchange rate (eq. 3), as in Nasir and Leung (2021) approach:

$$x_{jt,1(2)} = \Delta \mathrm{poil}_{jt}^{+(-)} = \left(poil_{jt} - poil_{jt-1}\right) \; iff \left(poil_{jt} - poil_{jt-1}\right) > (\langle)0; 0 \; otherwise \tag{2}$$

$$x_{jt,3} = XR_{jt}^{-} = \left(XR_{jt} - XR_{jt-1}\right) \; iff \left(XR_{jt} - XR_{jt-1}\right) < 0; 0 \; otherwise \tag{3}$$

Further, the variables (x_4, x_5) represent the *contagion index*, differentiated for upward and downward contagion:

$$x_{jt,4(5)} = Con_{jt}^{+(-)} \mathrm{I}\left(\sum\nolimits_{j=1;i\neq j}^{N} I\left(+(-)y_{jt} - c_j\right)\right) \tag{4}$$

with I(.) is the indicator function, which takes the value one if contemporaneously the log price change of each variable x_{jt} is greater than a predetermined threshold, $x_{jt} > c_j$, and value 0 otherwise. The predetermined threshold is taken at the extreme 5% of the empirical distribution of each variable. Eq. (4) shows the contagion effect defined as the possibility of sudden spreads of shocks originating in one variable to other variables. What contagion is still represents an open question (Edwards, 2000; Pericoli and Sbracia, 2003; Dungey et al., 2005) even if it can create volatility and serious damage to the economic system by spillover effects. Among others, Pesaran and Pick (2007) investigate the conditions under which contagion can be distinguished from mere interdependence. Accordingly, interdependence should represent the normal interacting conditions among markets while contagion should be an exceptional occurrence that arises only in specific conditions. These specificities must be identified according to well identified critical thresholds. When these thresholds are exceeded, it means that there is a sudden and significant increase in cross-variables links due to a shock in a specific variable. Finally, the FEVD derived from VAR-X (already done in many other papers, but without the spillover analysis) is used to measure the total and bilateral volatility spillovers of the different energy prices, exchange rates and inflation. Turning the attention to the direction of volatility spillovers (used also by Malik and Umar, 2019, but only analyzing oil price-exchange rate nexus), it is possible to identify different variables in different periods that are responsible as the major volatility spillover transmitters and receivers, among different oil prices, exchange rates and inflation. Accordingly, to Lütkepohl (2005), given that the VAR-X model is conditioned to the path of the exogenous variables, all the forecast error variance is explained by the structural shocks. This justifies a correct computation of the FEVD when applied in the structural VAR-X model. The spillover index is thus based on the generalized FEVD for a VAR(p) model at H-step ahead[2] forecast.

This approach provides a useful toolkit to compute the proportion of a shock from one macroeconomic variable that spills over to another (or group) of macroeconomic variable(s). This approach allows the policymaker to know what variable (or group of variables) is more vulnerable when another variable is hit by a shock.

Accordingly, to Diebold and Yilmaz, 2012; Diebold and Yılmaz, 2014) a generalized vector autoregressive framework is used and thus

[2] Different lengths of the forecasting horizon have checked, observing that the total spillover index assumes the maximum stable value at H = 30 for almost all countries.

FEVD is invariant to the variable ordering. Consequently, both the total and directional volatility spillovers are computed,[3] using the FEVD to assess the fraction of the H-step-ahead error variance in forecasting Y_i due to shocks to Y_j, $\forall i \neq j$. Given the usual moving average representation with the $N \times N$ coefficient matrices and the VAR-X representation (eq. 1) with $U_j \sim (0, \sum)$ vector of independent and identically distributed disturbances it is possible to represent some shock to Y_j with $(j = 1, 2, \ldots, N)$ and to Y_i with $(i = 1, 2, \ldots, N)$ and with $j \neq i$. It is possible to distinguish own and cross variance share as the fractions of the H-step-ahead error variances in forecasting Y_i that are due both to its own shock and shocks to other variables (spillover), respectively accordingly to the Diebold and Yilmaz (2012); Diebold and Yılmaz (2014) approach (see Appendix).

The implications for macroeconomic policy are important because the appraisal of the changes in magnitude and directions of the spillover relatively more or less intense on inflation (internal balance issue) or exchange rate (external balance issue) can be a guide for a more flexible, efficient, and responsive policy action.

5. Estimation results

This section reports the main results.[4] Given the preliminary stationarity and cointegration checks shown in the data section, the VAR-X model specified in eqs. (1)–(4) has been separately estimated for each country. In every VAR-X, there are four endogenous variables (Y_{jt}): the two oil prices of the main suppliers, the exchange rate, the inflation rate. Furthermore, there are 9 exogenous variables considered in the VAR, including structural determinants in order control for the main relationships.

In each country, the contagion effect on variable j is computed as a function of the extreme value indicator for all other variables except j. Therefore, when the threshold is reached in one market the indicator function is set to one, otherwise it is set to zero. This means that when a shock occurs in one variable, the contagion index is triggered for all other variables. The model has been estimated for two periods: the period pre-Covid shock Jan 2010 – Jan 2020, and the whole period Jan 2010 – Dec 2021.

A preliminary strategy of estimation from general to specific has considered a VAR-X with all the nine exogenous structural variables $(x_{1,.} - x_9)$. Subsequently, the VAR-X preferred specification is estimated, eliminating those exogenous variables which are non-significant in each country, based on the likelihood ratio test, and then a simple VAR is estimated excluding all 9 variables. The results of the estimation are summarized by the log likelihood values in Table 3, which reports the log likelihood values for the first period pre-Covid in cols. (1)–(3) and for the whole period in cols. (4)–(6).

In particular, the results are in: the VAR model (cols. (1) and (4)), for the hypothesis that all coefficients of the structural factors are equal to zero; the restricted preferred VAR-X model (cols. (2) and (5)); the full VAR-X model (cols (3) and (6)), for the hypothesis: all coefficients of structural factors are non-zero. In col. (7) there are the number of parameter restrictions to test model of col. (3) vs. (2) and model of col. (6) vs. (5), i.e., the restrictions of the preferred specification vs. the general one. It is evident from the comparison of cols. (2) and (3) as well as (5) and (6) for each country and for both periods that the exclusion restrictions are acceptable.

In addition, in col. (8) there are the number of parameter restrictions to test model of col. (2) vs. (1) and of (5) vs. (4), i.e., the restrictions of no structural effects vs. the preferred specification. The comparison of cols (1) and (2) as well as (4) and (5), for each country, and for both periods shows that the restriction of no structural factors is rejected. In conclusion, the preferred specification for each country for both periods is given by the results of estimation of cols. (2) and (5). The Chow test for the individual equations, for the preferred specification, testing the structural differences in the post Covid period is shown in Table 4.

The F-test threshold value at 5% is 1.94. It is evident that there have been some structural changes after the Covid shock, although not for all equations and all countries. We note that for all countries (except China, India, and Korea), at least two or three equations show a Chow test above the critical value. Considering the first two equations, pertaining to the two oil prices, we note a significant change in at least one for all 15 countries, and a change on both for 8 countries. For this reason, the analysis of the FEVD and the spillover effects has been conducted for both periods, to gather insight of the changes induced by the Covid crisis.

The empirical estimation of the model eqs. (1)–(4) for each country is used to assess four interesting testable hypotheses:

H1 There exist asymmetric effects of oil price changes.

H2 There is a significant effect of exchange rate depreciation and of some other structural variables.

H3 There exist asymmetric effects of contagion.

H4 Spillover effects differently affect macroeconomic variables and partner countries.

6. Discussion of the results

Focusing on the effects of structural variables X in eq. (1) for each country for both periods, the results of the estimation are reported in Table 5 (panel a and b). Recall that there are four equations for each country. The first rows labeled “Eq1” in panel (a), referring to the whole sample, report the coefficients of the nine structural variables in the first equation: positive and negative changes in oil prices (Dpoil+ and Dpoil-), exchange rate depreciation (XR-), positive and negative contagion effect (Con+ Con-), policy interest rate (Int rate), Unemployment rate, (Unempl), industrial production index (Prod ind), trade structure (Trade struct).

The following groups of nine rows are labeled “Eq2”, “Eq3” and “Eq4”, showing the coefficients of the structural variables in these equations.[5]

There emerge different results for different countries. For instance, considering an oil importing country like GE in Table 5 panel (a), it is possible to appreciate that the effect of Dpoil+ and Dpoil- are both significant for the first two equations, i.e., the oil price variables, and that the effect of Dpoil+ is significant for the XR equation, while the effect of Dpoil- is significant for the CPI equation.

In addition, the effects of XR- Con+ Con- are all significant for the XR and CPI equations and the effect of industrial production is significant

[3] Operationally, I avoid the order dependence extending the spillover index associated with an N-variable simple VAR, obtained by the Cholesky factor orthogonalization, to a measure of the directional spillovers derived from a generalized VAR framework.

[4] In the tables, the following labels are used: Dpoil+(−) for the negative change and positive change of oil price; XR for exchange rate; CPI for inflation; the oil supplier country (from Table 1) is indicated using UN/LOCODE Code List 2022–1 (UN 2022b). For instance: CPIAU is consumer price index of Australia, AU_ID is the oil price of imports of Australia from Indonesia.

[5] Comparing the two panels, the percentage of the parameters that become, or cease to be, significant is lower than 10% (50 out of 600). In detail, these parameters are 10 in Eq1 and Eq3; 14 in Eq2 and 16 in Eq4; each equation includes 150 parameters. Referring to the couple of variables Dpoil+(−) the number of changed parameters is 19, out of 240, meanwhile for XR- the number is 9 out of 120 and for Con+(−) is 22 out of 240. Finally, focusing on the single countries, there emerges that a parameter changes higher than 10% (i.e., >4 out of 40) occurs only in four countries (that is: FR 7; UK, ZA 6 and AU 5). Consequently, the scenario is quite stable, also considering every relevant change that has been adequately underlined and discussed in the paper.

Table 3
Log likelihood for the pre-Covid and whole sample estimation periods.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Country	Jan 2010 – Jan 2020			Jan 2010 – Dec 2021			No. restrictions	
AU	781.38	930.67	937.56	743.96	930.53	939.08	4	36
CA	388.28	577.58	582.14	397.34	586.54	597.64	8	36
BR	529.76	706.21	717.11	566.34	778.66	790.00	8	36
CN	754.86	1000.39	1004.13	821.98	1154.98	1158.68	4	32
FR	823.73	1029.10	1031.06	886.47	1065.76	1071.08	4	36
GE	829.43	1057.71	1058.39	884.55	1180.52	1182.86	12	36
IN	622.88	880.85	883.45	691.79	1009.61	1015.74	4	32
IT	862.35	1070.89	1075.48	922.19	1181.60	1188.44	4	36
JP	737.02	1071.71	1074.24	808.32	1216.52	1219.91	8	36
KR	751.16	941.59	946.94	792.84	1047.01	1057.43	8	36
RU	633.06	821.56	821.56	707.25	901.91	901.91	16	36
SA	644.10	844.18	844.18	703.45	882.93	882.93	16	36
ZA	504.90	664.29	665.06	523.23	699.70	701.33	12	36
UK	748.35	951.95	952.76	707.11	918.14	918.54	12	36
US	717.22	804.80	807.40	762.04	870.23	874.42	12	36

chi square values: $\chi^2(4) = 11.4$; $\chi^2(8) = 20.1$; $\chi^2(12) = 11.4$; $\chi^2(16) = 32.0$; $\chi^2(32) = 53.5$; $\chi^2(36) = 58.0$.

Table 4
Chow test for the sub-sample Jan 2010 – Jan 2021.

Country	Eq1	Eq2	Eq3	Eq4
AU	11.2	10.0	1.5	7.3
CA	3.3	2.2	2.1	1.3
BR	1.4	2.9	0.9	1.9
CN	2.5	1.5	0.6	1.2
FR	8.3	4.6	1.2	2.7
GE	1.8	2.5	0.8	3.5
IN	2.7	1.7	0.6	0.9
IT	3.3	4.0	1.1	1.6
JP	4.5	2.0	0.5	0.7
KR	1.6	6.9	0.4	1.0
RU	4.6	2.4	2.3	0.7
SA	1.3	2.4	1.4	3.1
ZA	1.8	4.5	1.8	2.1
UK	13.3	12.0	1.4	5.1
US	3.1	2.7	0.5	2.0

for the second oil price.

Essentially, the same results emerge for GE, looking at the period pre-Covid in Table 5 panel (b), with an additional significant effect of the interest rate and of unemployment in the CPI equation. Thus, in the case of GE there emerges a stable picture of the exogenous effects, that is characterized by some contagion for the macro variables (exchange rate and inflation) but not for the oil price variables, while the asymmetric oil changes affect only the oil variables. Considering as an oil exporting country like RU in Table 5 panel (a), we note that the effect of oil price change is significant only when it is negative on the inflation equation and on the second oil price equation (which is NL, thus essentially the European market). The effect of asymmetric contagion is mildly significant in the oil price equations and XR and CPI equations. However, looking at RU results in panel (b), i.e., in the period pre-Covid, notice that the Dpoil- and the contagion effects are more significant and there is also a significant effect of the negative exchange rate change on the oil and inflation equations. Thus, in the case of RU, it appears that the oil related structural effects have been weakened during the period post-Covid. On the contrary, unemployment, industrial production and trade structure appear to be more significant in the post Covid period. A comprehensive analysis of the results of Table 5 shows that the first three hypotheses H1, H2, H3 are confirmed, as discussed in detail below.

Regarding H1, which concerns the effects of oil price changes, results show that for the first two equations, that is the oil price variables for each country, the Dpoil+ ad Dpoil- are generally significant and asymmetric. In particular, the asymmetric effect is significant for both oil variables and both periods for: AU, CA, GE, IN, IT and ZA. For example, Donayre and Wilmot (2016) find that in the Canadian economy, there exists a significant asymmetry, especially during recessions or periods of low output growth, regarding inflation and oil price shock, indeed a negative correlation is larger than the positive one. With reference to the euro area, Conflitti and Cristadoro (2018) find that changes in oil prices have had, since the 2007 financial crisis, a significant impact on long-term inflation expectations, albeit with a certain heterogeneity in the results. In this paper, GE and IT confirm their result. Considering the BRICS countries, different results arise in accord with the literature (Nasir et al., 2018, Volkov and Yuhn, 2016). BR, IN, ZA and CN show an important asymmetrical effect of their oil prices, meanwhile RU exhibits only a significative downward effect of the oil price shock. These results are partially confirmed by the literature. On the one hand, Syzdykova et al. (2022) underline the existence of the downward effect for RU, but on the other hand, their results suggest the existence of the transmission from negative oil price shocks to positive inflation shocks. Furthermore, in this analysis, the results suggest that the increase or decrease in inflation rates is not only caused by oil prices. Li and Guo (2022) highlight the existence of significant asymmetries between oil prices and inflation in CN, that only occur in the short term, with the inflationary effect being more marked when the oil price decreases.

For JP, the effects are significant only in the estimation of the whole period. This result is coherent with previous studies' results such as: Beckmann et al. (2022) and Badel and McGillicuddy (2015). For the US only the Dpoil- is significant. This result is confirmed by literature that underlines how the decline in oil prices has affected both short-term and long-term inflation expectations (Conflitti and Cristadoro, 2018). By focusing on the variables Dpoil and comparing the two panels, the scenario is quite stable even if in some countries, i.e., FR, UK, ZA and SA, some changes arise. The impact of oil price shocks on FR and UK is not very significant, and this can be explained by the fact that FR has the largest share of nuclear power among the countries considered and the UK is the largest producer of oil in Europe. The later type of consideration is also applicable in SA that is among the largest oil exporting countries. Finally, ZA is among the countries most affected by oil price shocks. This is probably due to a complex system of determinants, ZA. For example, it is a net oil importer, and its transportation system highly depends on liquid fuels.

Regarding H2, which concerns the effect of exchange rate depreciation, results show that there is a significant for most of the countries of the variable XR-. In particular, the effect is significant in the exchange rate equation in CA, CN, IN, UK, and US. This result is confirmed by both Beckmann et al. (2020), who suggest the existence of strong links between exchange rates and oil prices over the long run for several countries, and Nasir and Vo (2020) who find a strong relationship between XR and inflation in UK and CA.

In AU, BR, IT and RU, the XR effect is significant in the inflation

Table 5
Coefficient estimation of structural variables (full period, Jan 2011 – Dec 2021).

Country		AU			BR			CA			CN			FR			GE			IN			IT		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
Panel a																									
Eq1	Dpoil+	1.305	[0.000]	***	0.465	[0.011]	**	1.094	[0.000]	***	0.839	[0.000]	***	0.699	[0.000]	***	1.154	[0.000]	***	0.921	[0.000]	***	19.684	[0.000]	***
	Dpoil-	1.030	[0.000]	***	1.060	[0.000]	***	2.004	[0.000]	***	1.114	[0.000]	***	0.960	[0.000]	***	0.841	[0.000]	***	1.087	[0.000]	***	24.678	[0.000]	***
	XR-	−0.595	[0.202]		0.478	[0.236]		−0.010	[0.991]		0.084	[0.800]		−0.624	[0.768]		0.288	[0.662]		0.004	[0.983]		0.698	[0.486]	
	Con+	−0.042	[0.048]	**	0.027	[0.096]	*	−0.003	[0.843]		−0.005	[0.243]		0.022	[0.091]	*	−0.003	[0.645]		0.002	[0.636]		0.848	[0.398]	
	Con-	0.024	[0.119]		0.025	[0.256]		0.000	[0.980]		0.007	[0.125]		−0.009	[0.370]		0.014	[0.063]	*	−0.004	[0.443]		2.202	[0.029]	**
	Int rate	0.005	[0.337]					−0.025	[0.244]		−0.030	[0.050]	**				−0.009	[0.268]		0.002	[0.434]		−0.500	[0.618]	
	Unempl				0.001	[0.852]								0.000	[0.992]		0.001	[0.822]							
	Prod ind							0.005	[0.118]								0.000	[0.369]							
	Trade struct				−0.202	[0.558]																			
Eq2	Dpoil+	0.772	[0.000]	***	1.662	[0.000]	***	0.888	[0.000]	***	1.053	[0.000]	***	0.967	[0.000]	***	0.981	[0.000]	***	0.958	[0.000]	***	21.278	[0.000]	***
	Dpoil-	0.881	[0.000]	***	0.908	[0.000]	***	0.587	[0.000]	***	1.064	[0.000]	***	1.006	[0.000]	***	0.985	[0.000]	***	1.055	[0.000]	***	23.575	[0.000]	***
	XR-	0.031	[0.935]		−0.204	[0.682]		0.337	[0.580]		−0.131	[0.699]		−1.106	[0.531]		−0.222	[0.682]		−0.166	[0.327]		−0.630	[0.530]	
	Con+	0.021	[0.208]		−0.011	[0.586]		0.012	[0.331]		0.004	[0.356]		−0.004	[0.687]		0.006	[0.233]		−0.001	[0.765]		−1.691	[0.093]	*
	Con-	−0.020	[0.109]		−0.025	[0.372]		0.013	[0.310]		−0.001	[0.877]		−0.006	[0.485]		0.008	[0.191]		−0.004	[0.340]		0.455	[0.650]	
	Int rate	−0.006	[0.205]					0.002	[0.908]		0.075	[0.000]	***				−0.007	[0.286]		−0.004	[0.037]	**	0.130	[0.896]	
	Unempl				−0.007	[0.413]								0.004	[0.480]		0.006	[0.252]							
	Prod ind							0.005	[0.069]	*							0.001	[0.002]	**						
	Trade struct				−0.051	[0.904]																			
Eq3	Dpoil+	0.048	[0.403]		−0.036	[0.535]		0.022	[0.472]		0.005	[0.839]		−0.003	[0.858]		0.030	[0.036]	***	−0.106	[0.010]	***	−1.912	[0.058]	**
	Dpoil-	0.010	[0.777]		−0.041	[0.350]		0.072	[0.001]	***	−0.015	[0.347]		0.008	[0.509]		−0.013	[0.217]		−0.001	[0.955]		−0.541	[0.590]	
	XR-	0.160	[0.180]		0.268	[0.039]	*	−0.167	[0.192]		0.525	[0.000]	***	−0.088	[0.729]		0.326	[0.015]	***	0.347	[0.006]	***	1.454	[0.148]	
	Con+	0.009	[0.093]	*	0.006	[0.284]		0.012	[0.000]	***	0.006	[0.000]	***	0.005	[0.001]	***	0.004	[0.005]	***	0.009	[0.004]	***	5.892	[0.000]	***
	Con-	−0.021	[0.000]	***	−0.031	[0.000]	***	0.000	[0.871]		−0.005	[0.007]	***	−0.002	[0.064]	*	−0.004	[0.009]	***	−0.012	[0.000]	***	−3.442	[0.001]	***
	Int rate	0.005	[0.001]	***				0.010	[0.003]	***	0.003	[0.639]					0.000	[0.998]		−0.003	[0.012]	**	0.392	[0.695]	
	Unempl				0.000	[0.819]								−0.001	[0.314]		0.000	[0.974]							
	Prod ind							−0.002	[0.000]	***							0.000	[0.450]							
	Trade struct				0.216	[0.051]	*																		
Eq4	Dpoil+	−0.502	[0.513]		−0.156	[0.790]		−0.505	[0.522]		−0.259	[0.837]		−0.077	[0.859]		−0.621	[0.233]		−1.128	[0.518]		0.908	[0.366]	
	Dpoil-	0.922	[0.049]	**	−0.286	[0.514]		−1.043	[0.068]	*	−1.905	[0.014]	**	0.335	[0.346]		1.070	[0.005]	***	−1.669	[0.072]	*	1.323	[0.188]	
	XR-	2.276	[0.159]		2.552	[0.050]	*	2.125	[0.522]		−2.354	[0.731]		−2.853	[0.706]		−12.347	[0.012]	**	−7.681	[0.150]		−2.865	[0.005]	***
	Con+	0.121	[0.096]	*	0.587	[0.000]	***	0.279	[0.000]	***	0.500	[0.000]	***	0.106	[0.020]	**	0.380	[0.000]	***	0.579	[0.000]	***	−0.955	[0.341]	
	Con-	−0.153	[0.005]	***	−0.155	[0.032]	**	−0.435	[0.000]	***	−0.671	[0.000]	***	−0.198	[0.000]	***	−0.327	[0.000]	***	−1.025	[0.000]	***	−2.464	[0.015]	**
	Int rate	−0.043	[0.027]	**				−0.163	[0.052]	*	−0.168	[0.594]					−0.042	[0.468]		0.080	[0.145]		−0.471	[0.638]	
	Unempl				−0.046	[0.039]	**							−0.033	[0.119]		0.007	[0.878]							
	Prod ind							0.032	[0.018]	**							−0.002	[0.382]							
	Trade struct				−2.012	[0.071]	*																		

Country		JP			KR			RU			SA			UK			US			ZA		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
Eq1	Dpoil+	0.919	[0.000]	***	0.937	[0.000]	***	1.148	[0.000]	***	0.312	[0.213]		1.294	[0.000]	***	0.344	[0.062]	*	0.594	[0.002]	***
	Dpoil-	0.898	[0.000]	***	1.096	[0.000]	***	0.771	[0.000]	***	0.111	[0.316]		0.353	[0.006]	***	0.319	[0.012]	**	0.767	[0.000]	***
	XR-	−0.046	[0.562]		0.449	[0.338]		0.032	[0.885]		−1.388	[0.244]		−0.153	[0.857]		−0.862	[0.346]		−0.437	[0.132]	
	Con+	0.007	[0.021]	**	0.003	[0.656]		−0.004	[0.550]		0.021	[0.081]	*	0.007	[0.552]		0.044	[0.000]	***	0.006	[0.770]	
	Con-	−0.006	[0.029]	**	0.006	[0.228]		−0.005	[0.493]		−0.006	[0.580]		−0.027	[0.022]	**	−0.020	[0.116]		−0.032	[0.068]	*
	Int rate	−0.019	[0.036]	**				−0.001	[0.573]		−0.010	[0.091]	*	−0.010	[0.165]		−0.004	[0.688]		−0.007	[0.293]	
	Unempl				0.005	[0.215]		−0.007	[0.098]	*	−0.013	[0.260]		−0.002	[0.604]		−0.014	[0.082]	*	0.002	[0.471]	
	Prod ind				0.001	[0.002]	**	0.000	[0.297]		−0.001	[0.422]		0.000	[0.613]		−0.001	[0.817]		−0.001	[0.435]	
	Trade struct	−0.152	[0.030]	**				0.266	[0.016]	**	−0.039	[0.716]										
Eq2	Dpoil+	0.987	[0.000]	***	0.880	[0.000]	***	1.101	[0.000]	***	1.148	[0.000]	***	1.354	[0.000]	***	0.695	[0.001]	***	1.462	[0.000]	***

(*continued on next page*)

Table 5 (*continued*)

Country		JP			KR			RU			SA			UK			US			ZA		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
	Dpoil-	1.042	[0.000]	***	0.800	[0.000]	***	0.475	[0.000]	***	1.604	[0.000]	***	1.855	[0.000]	***	0.910	[0.000]	***	0.962	[0.000]	***
	XR-	0.081	[0.359]		0.090	[0.893]		0.387	[0.196]		1.021	[0.364]		0.125	[0.914]		0.376	[0.718]		0.808	[0.017]	**
	Con+	−0.001	[0.690]		0.002	[0.831]		−0.006	[0.518]		−0.006	[0.585]		−0.007	[0.683]		0.031	[0.029]	**	−0.022	[0.324]	
	Con-	0.008	[0.012]	**	−0.002	[0.760]		−0.014	[0.136]		0.002	[0.843]		0.032	[0.046]	**	−0.022	[0.126]		−0.012	[0.543]	
	Int rate	0.004	[0.704]					0.002	[0.238]		0.006	[0.313]		0.009	[0.365]		0.016	[0.130]		0.007	[0.358]	
	Unempl				−0.008	[0.130]		−0.002	[0.741]		0.007	[0.498]		−0.004	[0.550]		0.022	[0.013]	**	−0.009	[0.015]	*
	Prod ind				−0.002	[0.000]	***	0.001	[0.030]	**	0.002	[0.208]		0.000	[0.982]		0.010	[0.030]	**	0.001	[0.554]	
	Trade struct	0.189	[0.016]	**				0.146	[0.318]		−0.044	[0.661]										
Eq3	Dpoil+	0.010	[0.849]		−0.054	[0.188]		0.193	[0.048]	**	−0.013	[0.851]		0.064	[0.229]		0.023	[0.489]		0.128	[0.156]	
	Dpoil-	−0.095	[0.002]	***	0.000	[0.984]		0.127	[0.040]	**	−0.039	[0.202]		−0.052	[0.162]		−0.115	[0.000]	***	0.203	[0.003]	***
	XR-	0.224	[0.095]	*	0.488	[0.113]		−0.167	[0.517]		0.116	[0.719]		−0.248	[0.326]		0.473	[0.006]	***	0.157	[0.259]	
	Con+	0.003	[0.498]		0.000	[0.989]		−0.013	[0.088]	*	0.004	[0.210]		−0.003	[0.469]		0.003	[0.165]		0.002	[0.822]	
	Con-	−0.012	[0.014]	**	−0.003	[0.276]		−0.024	[0.003]	***	0.002	[0.459]		−0.026	[0.000]	***	−0.003	[0.184]		0.010	[0.228]	
	Int rate	−0.022	[0.139]					0.000	[0.855]		−0.003	[0.093]	*	0.002	[0.468]		−0.003	[0.095]		0.004	[0.194]	
	Unempl				−0.001	[0.803]		0.004	[0.383]		−0.004	[0.195]		−0.001	[0.292]		−0.003	[0.020]	**	−0.001	[0.711]	
	Prod ind				0.000	[0.034]	*	0.000	[0.561]		−0.001	[0.025]	**	0.000	[0.240]		0.000	[0.688]		−0.001	[0.227]	
	Trade struct	0.308	[0.009]	***				0.191	[0.131]		−0.045	[0.127]										
Eq4	Dpoil+	−0.781	[0.373]		−2.059	[0.035]	**	−0.506	[0.705]		1.220	[0.824]		−1.926	[0.038]	**	1.200	[0.206]		−2.167	[0.068]	*
	Dpoil-	−0.345	[0.471]		0.358	[0.542]		−0.310	[0.715]		−1.812	[0.456]		0.639	[0.327]		1.874	[0.004]	***	1.657	[0.064]	*
	XR-	1.037	[0.632]		1.606	[0.823]		−7.727	[0.032]	**	−14.333	[0.583]		−2.336	[0.595]		0.232	[0.961]		−4.017	[0.030]	**
	Con+	0.177	[0.027]	**	0.297	[0.006]	***	0.497	[0.000]	***	−0.204	[0.443]		0.277	[0.000]	***	0.165	[0.010]	**	0.276	[0.027]	**
	Con-	−0.273	[0.001]	***	−0.345	[0.000]	***	−0.034	[0.752]		−0.585	[0.010]	**	−0.086	[0.155]		−0.203	[0.002]	***	−0.058	[0.601]	
	Int rate	0.355	[0.140]					0.029	[0.222]		−0.082	[0.538]		0.058	[0.114]		−0.099	[0.035]	**	−0.070	[0.096]	*
	Unempl				0.038	[0.519]		0.003	[0.960]		0.421	[0.101]		−0.010	[0.668]		−0.035	[0.380]		0.004	[0.850]	
	Prod ind				0.003	[0.542]		0.007	[0.131]		−0.016	[0.635]		0.006	[0.068]	*	−0.022	[0.278]		0.021	[0.010]	**
	Trade struct	−1.246	[0.510]					3.366	[0.054]	*	0.989	[0.674]										

Country		AU			BR			CA			CN			FR			GE			IN			IT		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
panel b																									
Eq1	Dpoil+	1.024	[0.000]	***	0.320	[0.090]	*	0.837	[0.000]	***	0.917	[0.000]	***	0.864	[0.000]	***	1.002	[0.000]	***	1.009	[0.000]	***	1.006	[0.000]	***
	Dpoil-	1.144	[0.000]	***	0.943	[0.000]	***	2.021	[0.000]	***	0.939	[0.000]	***	1.313	[0.000]	***	0.765	[0.000]	***	1.111	[0.000]	***	0.751	[0.000]	***
	XR-	−0.018	[0.950]		−0.444	[0.256]		−0.082	[0.926]		0.205	[0.499]		−0.131	[0.926]		0.036	[0.953]		0.051	[0.779]		−0.703	[0.212]	
	Con+	0.011	[0.380]		0.017	[0.254]		0.006	[0.727]		−0.003	[0.374]		0.004	[0.682]		−0.003	[0.639]		0.004	[0.339]		0.008	[0.270]	
	Con-	0.006	[0.516]		0.028	[0.188]		−0.003	[0.864]		0.001	[0.871]		0.011	[0.125]		0.003	[0.674]		−0.007	[0.101]		−0.004	[0.492]	
	Int rate	−0.003	[0.536]					−0.039	[0.185]		−0.046	[0.002]	***				−0.027	[0.025]	**	0.000	[0.995]		−0.005	[0.147]	
	Unempl				−0.005	[0.498]								0.011	[0.034]	**	0.017	[0.057]	*						
	Prod ind							0.012	[0.011]	**							0.000	[0.828]							
	Trade struct				−0.039	[0.905]																			
Eq2	Dpoil+	0.969	[0.000]	***	1.742	[0.000]	***	0.764	[0.000]	***	0.979	[0.000]	***	1.089	[0.000]	***	1.128	[0.000]	***	0.939	[0.000]	***	0.901	[0.000]	***
	Dpoil-	0.959	[0.000]	***	1.682	[0.000]	***	0.503	[0.000]	***	1.148	[0.000]	***	1.007	[0.000]	***	1.025	[0.000]	***	1.070	[0.000]	***	1.243	[0.000]	***
	XR-	0.121	[0.610]		0.186	[0.723]		0.136	[0.810]		−0.239	[0.476]		−2.443	[0.087]	*	0.070	[0.884]		−0.170	[0.320]		−0.341	[0.528]	
	Con+	−0.010	[0.334]		0.013	[0.503]		0.014	[0.249]		0.000	[0.989]		−0.016	[0.087]	*	−0.005	[0.359]		−0.001	[0.797]		−0.001	[0.912]	
	Con-	0.006	[0.406]		0.003	[0.902]		−0.001	[0.923]		−0.004	[0.465]		−0.007	[0.374]		0.005	[0.366]		−0.006	[0.149]		0.002	[0.666]	
	Int rate	0.003	[0.409]					0.020	[0.292]		0.080	[0.000]	***				−0.001	[0.952]		−0.001	[0.580]		0.003	[0.412]	
	Unempl				0.003	[0.719]								−0.003	[0.519]		0.003	[0.701]							
	Prod ind							−0.001	[0.656]								0.001	[0.043]	**						
	Trade struct				0.513	[0.237]																			
Eq3	Dpoil+	0.006	[0.926]		0.009	[0.887]		0.006	[0.861]		0.004	[0.909]		−0.019	[0.369]		0.032	[0.163]		−0.091	[0.099]	*	−0.057	[0.003]	***
	Dpoil-	0.032	[0.427]		−0.069	[0.214]		0.080	[0.001]	***	−0.001	[0.974]		0.028	[0.096]	*	0.003	[0.869]		0.021	[0.564]		0.026	[0.095]	*
	XR-	0.290	[0.019]	**	0.302	[0.029]	**	−0.150	[0.289]		0.526	[0.001]	***	−0.127	[0.628]		0.284	[0.042]	**	0.433	[0.002]	***	0.143	[0.267]	

(*continued on next page*)

Table 5 (*continued*)

Country		AU			BR			CA			CN			FR			GE			IN			IT		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
	Con+	0.011	[0.051]	*	0.001	[0.800]		0.012	[0.000]	***	0.006	[0.002]	***	0.007	[0.000]	***	0.003	[0.028]	**	0.007	[0.027]	**	0.010	[0.000]	***
	Con-	−0.022	[0.000]	***	−0.031	[0.000]	***	−0.001	[0.840]		−0.006	[0.009]	***	−0.003	[0.014]	**	−0.005	[0.004]	***	−0.014	[0.000]	***	−0.004	[0.010]	**
	Int rate	0.006	[0.003]	***				0.010	[0.039]	**	0.005	[0.531]					−0.002	[0.410]		−0.003	[0.024]	**	−0.001	[0.309]	
	Unempl				0.003	[0.232]								−0.001	[0.523]		0.002	[0.412]							
	Prod ind							−0.002	[0.002]	***							0.000	[0.404]							
	Trade struct				0.400	[0.001]	***																		
Eq4	Dpoil+	0.362	[0.525]		0.157	[0.825]		−0.740	[0.395]		0.072	[0.962]		0.823	[0.151]		−0.412	[0.531]		−0.802	[0.721]		1.115	[0.130]	
	Dpoil-	0.189	[0.614]		−0.395	[0.508]		−1.097	[0.056]	**	−3.606	[0.002]	***	−0.622	[0.163]		1.691	[0.001]	***	0.354	[0.816]		0.743	[0.216]	
	XR-	0.103	[0.928]		0.463	[0.754]		4.081	[0.222]		0.818	[0.907]		−3.147	[0.649]		−8.484	[0.036]	**	−3.633	[0.528]		−9.568	[0.057]	*
	Con+	0.028	[0.590]		0.537	[0.000]	***	0.255	[0.000]	***	0.492	[0.000]	***	0.083	[0.061]	*	0.315	[0.000]	***	0.542	[0.000]	***	−0.050	[0.418]	
	Con-	−0.098	[0.007]	***	−0.120	[0.132]		−0.392	[0.000]	***	−0.551	[0.000]	***	−0.163	[0.000]	***	−0.282	[0.000]	***	−0.945	[0.000]	***	−0.066	[0.217]	
	Int rate	−0.012	[0.515]					−0.020	[0.856]		−0.281	[0.414]					0.145	[0.059]	*	0.113	[0.057]	*	0.068	[0.035]	
	Unempl				−0.072	[0.007]	***							−0.045	[0.080]	*	−0.105	[0.065]	*						
	Prod ind							0.018	[0.301]								−0.001	[0.601]							
	Trade struct				−1.422	[0.246]																			

Country		JP			KR			RU			SA			ZA			UK			US		
Eq/Var		Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
Eq1	Dpoil+	0.948	[0.000]	***	0.898	[0.000]	***	1.208	[0.000]	***	0.566	[0.062]	*	0.616	[0.002]	***	1.126	[0.000]	***	0.225	[0.265]	
	Dpoil-	0.940	[0.000]	***	1.141	[0.000]	***	0.901	[0.000]	***	0.372	[0.034]	**	0.754	[0.000]	***	1.168	[0.000]	***	0.779	[0.000]	***
	XR-	−0.037	[0.553]		0.601	[0.195]		0.089	[0.632]		−1.881	[0.128]		−0.450	[0.163]		0.498	[0.292]		0.722	[0.381]	
	Con+	0.003	[0.265]		0.004	[0.591]		0.000	[0.976]		0.019	[0.151]		0.009	[0.680]		0.004	[0.558]		0.032	[0.005]	***
	Con-	−0.005	[0.065]	*	0.004	[0.441]		−0.012	[0.048]	*	−0.005	[0.682]		−0.032	[0.096]	*	−0.010	[0.109]		−0.019	[0.091]	*
	Int rate	−0.008	[0.271]					0.000	[0.961]		−0.008	[0.261]		0.015	[0.433]		0.003	[0.352]		0.020	[0.070]	*
	Unempl				0.005	[0.271]		−0.008	[0.029]	**	−0.032	[0.112]		−0.008	[0.430]		−0.008	[0.600]		−0.045	[0.001]	***
	Prod ind				0.001	[0.049]	**	0.000	[0.813]		−0.002	[0.307]		−0.004	[0.083]	*	−0.001	[0.273]		0.004	[0.052]	*
	Trade struct	−0.097	[0.131]					0.061	[0.543]		−0.047	[0.759]										
Eq2	Dpoil+	0.949	[0.000]	***	0.912	[0.000]	***	0.864	[0.000]	***	1.486	[0.000]	***	1.439	[0.000]	***	1.376	[0.000]	***	0.189	[0.441]	
	Dpoil-	0.923	[0.000]	***	0.776	[0.000]	***	0.521	[0.000]	***	1.789	[0.000]	***	0.957	[0.000]	***	0.967	[0.000]	***	0.863	[0.000]	***
	XR-	0.022	[0.795]		0.649	[0.173]		0.216	[0.454]		2.436	[0.023]	**	0.278	[0.362]		−0.418	[0.538]		−0.180	[0.857]	
	Con+	0.002	[0.646]		0.004	[0.628]		−0.002	[0.866]		−0.010	[0.346]		−0.035	[0.074]	*	−0.007	[0.521]		0.046	[0.001]	***
	Con-	0.001	[0.867]		−0.007	[0.174]		−0.013	[0.171]		0.018	[0.086]	*	0.000	[0.983]		0.008	[0.406]		−0.021	[0.134]	
	Int rate	0.006	[0.570]					0.002	[0.544]		0.009	[0.168]		−0.041	[0.021]	**	−0.005	[0.277]		0.012	[0.369]	
	Unempl				−0.011	[0.019]	**	0.004	[0.527]		0.032	[0.061]	*	0.018	[0.054]	*	−0.009	[0.668]		−0.043	[0.006]	***
	Prod ind				0.000	[0.210]		0.001	[0.056]	*	0.003	[0.116]		0.002	[0.356]		0.001	[0.373]		0.003	[0.335]	
	Trade struct	0.164	[0.057]	*				0.077	[0.621]		0.105	[0.425]										
Eq3	Dpoil+	0.082	[0.342]		−0.070	[0.285]		0.169	[0.141]		0.052	[0.520]		0.215	[0.026]	**	0.059	[0.314]		0.003	[0.946]	
	Dpoil-	−0.184	[0.001]	***	−0.012	[0.760]		0.412	[0.000]	***	−0.088	[0.061]	***	0.063	[0.490]		−0.178	[0.000]	***	−0.064	[0.062]	*
	XR-	0.201	[0.171]		0.536	[0.124]		0.159	[0.526]		0.165	[0.618]		0.112	[0.470]		−0.162	[0.520]		0.562	[0.005]	***
	Con+	−0.001	[0.880]		0.001	[0.875]		−0.005	[0.505]		0.001	[0.717]		0.002	[0.841]		0.000	[0.952]		0.003	[0.330]	
	Con-	−0.020	[0.002]	***	−0.003	[0.401]		−0.015	[0.076]	*	−0.002	[0.589]		0.004	[0.673]		−0.030	[0.000]	***	−0.004	[0.160]	
	Int rate	−0.019	[0.276]					0.002	[0.393]		−0.004	[0.046]	**	0.010	[0.252]		0.001	[0.535]		−0.002	[0.498]	
	Unempl				0.001	[0.713]		0.002	[0.707]		−0.005	[0.319]		0.001	[0.799]		−0.018	[0.022]	**	−0.001	[0.727]	
	Prod ind				0.000	[0.132]		0.000	[0.353]		−0.001	[0.037]	**	−0.003	[0.006]	***	0.000	[0.088]	*	0.001	[0.012]	**
	Trade struct	0.201	[0.182]					0.064	[0.636]		−0.081	[0.052]	*									
Eq4	Dpoil+	−2.815	[0.040]	**	−3.438	[0.017]	**	−2.670	[0.147]		6.262	[0.271]		−3.096	[0.013]	**	−2.769	[0.001]	***	−0.495	[0.665]	
	Dpoil-	−0.338	[0.700]		−0.237	[0.776]		0.229	[0.876]		−3.173	[0.334]		2.072	[0.077]	*	0.969	[0.138]		1.522	[0.061]	*
	XR-	0.965	[0.675]		1.025	[0.892]		−7.687	[0.057]	*	6.956	[0.765]		−4.927	[0.014]	**	−0.818	[0.810]		−0.289	[0.951]	
	Con+	0.322	[0.002]	***	0.306	[0.022]	**	0.532	[0.000]	***	−0.366	[0.136]		0.269	[0.037]	**	0.212	[0.000]	***	0.124	[0.051]	*
	Con-	−0.252	[0.012]	**	−0.377	[0.000]	***	−0.037	[0.780]		−0.375	[0.105]		−0.025	[0.832]		−0.068	[0.140]		−0.225	[0.001]	***
	Int rate	0.349	[0.206]					0.092	[0.010]	*	−0.152	[0.277]		0.029	[0.799]		0.088	[0.001]	***	0.074	[0.242]	

(*continued on next page*)

Table 5 (*continued*)

Country	JP			KR			RU			SA			ZA			UK			US		
Eq/Var	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig	Coef	PVal	Sig
Unempl				0.064	[0.380]		−0.019	[0.820]		0.626	[0.098]	*	−0.123	[0.039]	**	0.101	[0.343]		0.012	[0.870]	
Prod ind				0.000	[0.969]		0.012	[0.049]	**	−0.046	[0.224]		−0.005	[0.746]		−0.005	[0.136]		−0.005	[0.715]	
Trade struct	−2.144	[0.366]					5.790	[0.009]	***	−0.542	[0.852]										

equations and in both equations for GE, while the effect is not evident in the remaining countries confirming that there exists a considerable amount of country-level heterogeneity (Nasir and Vo, 2020).

This result is interesting because it confirms the validity of the methodology of investigation of Nasir and Leung (2021) and it expands the scope of the analysis of the asymmetric XR effects. The implication is that the depreciation has significant effects on major currencies like USD, UK pound, Euro, Chinese Yuan, India Rupia, but it has also an impact on inflation in other countries like AU, BR, IT and RU. Finally, referring to the ZA Covid has especially hit XR and contagion equations. This possibly reflects the fact that the balance of payments highly vulnerable and that the important exposure to the capital flight heavily affected the XR. In addition, policy interest rates and unemployment have significant effects on oil price and CPI equations, and it is interesting to note that the trade structure has some significant effect only on the equations of Japan, Russia, and Saudi Arabia, which are countries certainly open to trade, even with very different specializations.

Regarding H3, which concerns the existence of contagion effects, results show that there exists indeed some contagion and that it is exhibiting asymmetric characteristics, for Con+ and Con− coefficients are statistically significant and the signs are as expected. In other words, results suggest that, when there is contagion, the effect is generally asymmetric and, as expected, the positive contagion has a positive coefficient, while the negative one has a negative coefficient.

Turning the attention to estimations, in Table 5 the contagion coefficients are significant for many countries, and especially for the XR and CPI equations, both positive and negative effects are significant. The contagion effect is significant on the XR and inflation equations of CA, CN, GE, IN, IT, JP and US. It is significant only the positive effect on the oil price equations of AU, BR, JP, SA, and US and it is significant only the negative effect on the oil price equations of GE, IT, JP, UK, and ZA. These results are very interesting, suggesting that oil prices upsurge has more effect on oil exporting countries (except for JP) as compared to oil importing countries and the oil price downfall has more effect on large oil importing economies as compared to small countries. These results are coherently with Hameed et al. (2021).

6.1. *The FEVD analysis*

The FEVD analysis is reported in Table 6 and for each country four different results are reported: the decomposition based on orthogonal and generalized impulse response for both periods, in the left part the whole period and in the right part the period pre-Covid. For instance, results for AU are reported in the four top boxes: "AU full sample" reports the Cholesky (labeled "CHO") decomposition above and the Generalized (labeled "GEN") below. Next, "AU Pre-Covid period" reports the same for the period of estimation Jan 2010-Jan 2020.

The rows are labeled Eq1-Eq4, while the columns are labeled with the acronym reported in Table 1 for easier reading. For instance, considering AU, we note that the proportion of the forecast error of Eq1, derived from the price of oil from ID is 28.16%, under the Choleski decomposition. Along the diagonal, the value for Eq 2 is 66.0%, for Eq3 is 68.17%, for Eq4 is 66.43%. The results show very interesting patterns, highlighted as follows.

First, in the Cholesky decomposition, there are many cases in which the own FEVD contribution is systematically lower in the whole period for two or more equations: BR, CA, IT, FR, IN, KR, SA, UK, US and the reverse for the largest Asian countries, Germany, Russia and South Africa: AU, CN, GE, JP, RU, ZA. These results could hint that after the Covid there has been an intensification of the international transmission of the shocks from larger countries.

Second, comparing the Cholesky to the generalized decomposition, it is evident in many countries that the Cholesky own FEVD contribution is lower for the oil price and the exchange rate variables, and only in some cases it is higher for the CPI. For instance, in the case of CA, the whole period the Cholesky-based FEVD contribution of CPI is 85.30% while the

Table 6
FEVD orthogonal and generalized.

FEVD	AU full sample				AU pre-Covid period				BR full sample				BR pre-Covid period			
CHO	ID	MY	XR	CPI	ID	MY	XR	CPI	SA	US	XR	CPI	SA	US	XR	CPI
Eq1	28.16	57.03	5.58	9.23	49.69	46.23	1.35	2.73	41.89	37.85	16.53	3.73	44.48	37.72	7.59	10.20
Eq2	26.29	66.00	4.08	3.63	38.20	60.89	0.52	0.40	19.31	72.91	7.08	0.71	25.89	70.80	1.48	1.83
Eq3	10.84	1.02	68.17	19.98	0.21	3.68	69.99	26.11	24.00	7.92	67.47	0.61	2.02	5.93	91.87	0.17
Eq4	3.21	2.74	27.62	66.43	3.97	1.63	2.88	91.52	31.46	18.32	21.63	28.59	0.42	1.40	30.06	68.11
GEN	ID	MY	XR	CPI	ID	MY	XR	CPI	SA	US	XR	CPI	SA	US	XR	CPI
Eq1	28.16	57.03	5.58	9.23	49.69	46.23	1.35	2.73	41.89	37.85	16.53	3.73	44.48	37.72	7.59	10.20
Eq2	70.70	21.59	4.08	3.63	37.89	61.19	0.52	0.40	37.05	55.16	7.08	0.71	36.72	59.97	1.48	1.83
Eq3	4.66	3.91	71.46	19.98	0.04	3.63	70.21	26.11	22.41	3.48	73.50	0.61	3.54	6.07	90.22	0.17
Eq4	0.36	0.43	30.18	69.04	0.51	0.91	5.07	93.51	40.87	1.11	25.83	32.19	0.56	2.31	16.32	80.80
FEVD	CA full sample				CA pre-Covid period				CN full sample				CN pre-Covid period			
CHO	ID	MY	XR	CPI	ID	MY	XR	CPI	SA	US	XR	CPI	SA	US	XR	CPI
Eq1	52.70	12.34	32.38	2.57	30.41	33.01	34.49	2.10	63.86	34.63	1.35	0.16	55.10	31.52	1.74	11.65
Eq2	24.13	38.02	37.38	0.46	13.00	56.33	29.12	1.55	55.20	40.96	3.06	0.77	47.69	36.13	3.39	12.79
Eq3	10.81	2.79	85.40	1.00	4.18	15.19	72.22	8.41	8.23	3.04	87.97	0.75	9.49	3.68	86.20	0.63
Eq4	2.42	0.88	11.40	85.30	0.35	1.55	3.32	94.77	4.75	5.60	15.14	74.51	1.13	2.47	29.61	66.78
GEN	ID	MY	XR	CPI	ID	MY	XR	CPI	SA	US	XR	CPI	SA	US	XR	CPI
Eq1	52.70	12.34	32.38	2.57	30.41	33.01	34.49	2.10	63.86	34.63	1.35	0.16	55.10	31.52	1.74	11.65
Eq2	34.90	27.25	37.38	0.46	32.72	36.61	29.12	1.55	58.56	37.61	3.06	0.77	47.81	36.01	3.39	12.79
Eq3	19.54	1.05	78.41	1.00	18.20	7.89	65.50	8.41	4.28	0.34	94.62	0.75	7.27	0.83	91.27	0.63
Eq4	3.65	0.39	12.12	83.84	0.72	0.23	5.22	93.82	4.44	1.09	2.74	91.74	0.87	0.12	16.90	82.11
FEVD	FR full sample				FR pre-Covid period				GE full sample				GE pre-Covid period			
CHO	SA	RU	XR	CPI	SA	RU	XR	CPI	RU	NO	XR	CPI	RU	NO	XR	CPI
Eq1	12.00	68.20	1.40	18.40	28.13	57.25	3.62	11.00	27.83	71.28	0.40	0.49	34.11	56.55	1.64	7.70
Eq2	4.78	72.52	1.48	21.22	20.23	66.04	2.54	11.19	25.85	73.15	0.34	0.66	31.20	60.45	1.65	6.70
Eq3	2.53	22.98	71.29	3.20	5.27	11.43	80.92	2.38	7.88	8.88	83.12	0.12	4.41	1.60	77.36	16.63
Eq4	3.72	3.09	5.31	87.88	15.14	2.54	14.55	67.77	2.88	4.81	4.41	87.90	0.87	0.99	14.03	84.11
GEN	SA	RU	XR	CPI	SA	RU	XR	CPI	RU	NO	XR	CPI	RU	NO	XR	CPI
Eq1	12.00	68.20	1.40	18.40	28.13	57.25	3.62	11.00	27.83	71.28	0.40	0.49	34.11	56.55	1.64	7.70
Eq2	12.47	64.83	1.48	21.22	55.35	30.92	2.54	11.19	14.78	84.22	0.34	0.66	13.35	78.30	1.65	6.70
Eq3	2.42	17.10	77.28	3.20	6.87	4.02	86.73	2.38	2.38	9.35	88.15	0.12	0.57	0.72	82.07	16.63
Eq4	6.30	2.88	6.18	84.64	3.03	5.97	23.88	67.13	0.43	1.27	20.53	77.77	0.54	0.30	0.38	98.78
FEVD	IT full sample				IT pre-Covid period				IN full sample				IN pre-Covid period			
CHO	RU	AZ	XR	CPI	RU	AZ	XR	CPI	IQ	SA	XR	CPI	IQ	SA	XR	CPI
Eq1	48.08	37.26	1.07	13.59	42.07	50.94	5.78	1.21	49.99	28.30	11.22	10.48	57.00	34.15	6.96	1.90
Eq2	46.79	40.24	2.02	10.95	39.31	54.14	5.44	1.10	42.08	35.27	9.28	13.38	50.21	41.50	5.52	2.77
Eq3	13.33	9.90	63.91	12.86	5.59	10.75	79.29	4.37	2.65	4.35	53.02	39.98	2.27	5.26	54.48	37.98
Eq4	1.82	0.50	27.40	70.29	1.83	2.85	14.03	81.28	0.71	3.31	5.96	90.02	0.53	4.68	6.38	88.41
GEN	RU	AZ	XR	CPI	RU	AZ	XR	CPI	IQ	SA	XR	CPI	IQ	SA	XR	CPI
Eq1	48.08	37.26	1.07	13.59	42.07	50.94	5.78	1.21	49.99	28.30	11.22	10.48	57.00	34.15	6.96	1.90
Eq2	25.52	61.51	2.02	10.95	8.71	84.74	5.44	1.10	24.60	52.75	9.28	13.38	41.58	50.13	5.52	2.77
Eq3	11.23	11.23	64.68	12.86	2.66	11.82	81.15	4.37	1.04	5.72	53.26	39.98	0.95	5.67	55.40	37.98
Eq4	3.60	0.60	21.12	74.69	1.79	3.18	18.42	76.61	0.49	2.49	14.17	82.85	0.34	2.11	19.82	77.72
FEVD	JP full sample				JP pre-Covid period				KR full sample				KR pre-Covid period			
CHO	SA	AE	XR	CPI	SA	AE	XR	CPI	SA	AE	XR	CPI	SA	AE	XR	CPI
Eq1	17.53	78.15	0.34	3.97	31.44	53.32	9.25	5.99	72.94	25.41	1.14	0.51	74.03	17.25	8.20	0.53
Eq2	13.36	82.37	1.51	2.76	28.50	60.85	6.11	4.54	61.10	34.67	0.29	3.95	72.02	21.13	6.60	0.26
Eq3	0.98	0.16	90.53	8.33	2.79	0.26	82.06	14.90	8.60	1.85	48.71	40.84	2.18	0.70	66.26	30.85
Eq4	1.32	0.85	45.25	52.59	3.21	0.05	50.66	46.08	3.57	0.44	9.72	86.27	1.24	1.85	15.11	81.80
GEN	SA	AE	XR	CPI	SA	AE	XR	CPI	SA	AE	XR	CPI	SA	AE	XR	CPI
Eq1	17.53	78.15	0.34	3.97	31.44	53.32	9.25	5.99	72.94	25.41	1.14	0.51	74.03	17.25	8.20	0.53
Eq2	28.89	66.84	1.51	2.76	52.19	37.16	6.11	4.54	66.45	29.31	0.29	3.95	56.45	36.70	6.60	0.26
Eq3	0.06	0.29	91.31	8.33	0.20	0.85	84.06	14.90	8.09	3.17	47.91	40.84	3.42	0.75	64.97	30.85
Eq4	1.41	0.33	44.19	54.07	1.40	0.44	49.06	49.09	0.05	0.77	10.06	89.12	0.07	1.34	17.57	81.02
FEVD	RU full sample				RU pre-Covid period				SA full sample				SA pre-Covid period			
CHO	CN	NL	XR	CPI	CN	NL	XR	CPI	CN	JP	XR	CPI	CN	JP	XR	CPI
Eq1	70.72	25.01	0.26	4.01	48.21	48.09	0.52	3.18	13.87	82.43	1.25	2.46	48.02	38.02	11.11	2.85
Eq2	69.66	26.31	0.23	3.80	46.67	49.65	0.69	2.99	6.03	88.79	1.45	3.74	30.90	42.10	21.04	5.96
Eq3	23.41	11.50	62.55	2.55	18.70	21.59	58.48	1.23	0.16	27.27	68.70	3.87	0.12	13.02	83.59	3.27
Eq4	18.10	11.04	3.16	67.70	12.10	17.00	0.35	70.55	0.25	35.97	36.16	27.61	0.47	16.52	49.29	33.72
GEN	CN	NL	XR	CPI	CN	NL	XR	CPI	CN	JP	XR	CPI	CN	JP	XR	CPI
Eq1	70.72	25.01	0.26	4.01	48.21	48.09	0.52	3.18	13.87	82.43	1.25	2.46	48.02	38.02	11.11	2.85
Eq2	46.02	49.94	0.23	3.80	38.83	57.49	0.69	2.99	31.70	63.12	1.45	3.74	17.22	55.78	21.04	5.96
Eq3	15.17	18.07	64.20	2.55	15.60	25.37	57.79	1.23	3.35	8.48	84.30	3.87	1.77	2.54	92.42	3.27
Eq4	12.95	13.51	3.49	70.06	10.51	15.85	2.02	71.62	36.50	14.46	21.38	27.66	52.77	10.18	6.37	30.67

(*continued on next page*)

Table 6 (*continued*)

FEVD	AU full sample				AU pre-Covid period				BR full sample				BR pre-Covid period			
CHO	ID	MY	XR	CPI	ID	MY	XR	CPI	SA	US	XR	CPI	SA	US	XR	CPI
FEVD	UK full sample				UK pre-Covid period				US full sample				US pre-Covid period			
CHO	NO	NG	XR	CPI	NO	NG	XR	CPI	CA	KR	XR	CPI	CA	KR	XR	CPI
Eq1	9.12	75.12	10.18	5.58	53.54	39.13	4.35	2.99	43.82	12.73	22.04	21.41	43.40	2.34	46.59	7.66
Eq2	1.31	83.12	6.59	8.98	50.23	43.02	4.01	2.74	36.66	24.67	20.11	18.56	40.96	7.62	44.48	6.94
Eq3	2.29	24.79	14.56	58.37	5.40	3.92	80.57	10.11	1.26	2.92	48.79	47.02	26.71	0.59	61.65	11.05
Eq4	4.68	9.43	0.88	85.01	15.06	12.59	36.53	35.81	3.07	5.68	4.57	86.68	5.39	0.08	6.40	88.13
GEN	NO	NG	XR	CPI	NO	NG	XR	CPI	CA	KR	XR	CPI	CA	KR	XR	CPI
Eq1	9.12	75.12	10.18	5.58	53.54	39.13	4.35	2.99	43.82	12.73	22.04	21.41	43.40	2.34	46.59	7.66
Eq2	24.27	60.16	6.59	8.98	54.75	38.50	4.01	2.74	8.70	52.63	20.11	18.56	14.89	33.69	44.48	6.94
Eq3	1.79	22.53	17.31	58.37	2.28	2.34	85.28	10.11	0.53	3.90	48.55	47.02	5.00	12.70	71.25	11.05
Eq4	0.89	11.39	3.37	84.35	10.02	11.23	35.74	43.00	1.27	11.07	8.73	78.92	0.21	0.54	2.33	96.92
FEVD	ZA full sample				ZA pre-Covid period											
CHO	AN	NG	XR	CPI	AN	NG	XZA	CPI								
Eq1	44.26	54.96	0.10	0.68	45.29	51.65	0.19	2.87								
Eq2	32.80	66.77	0.04	0.39	31.96	63.49	0.29	4.26								
Eq3	10.43	2.90	84.38	2.29	7.47	16.06	73.56	2.91								
Eq4	0.09	6.53	4.60	88.79	5.27	8.57	29.07	57.10								
GEN	AN	NG	XR	CPI	AN	NG	XZA	CPI								
Eq1	44.26	54.96	0.10	0.68	45.29	51.65	0.19	2.87								
Eq2	54.94	44.62	0.04	0.39	56.81	38.64	0.29	4.26								
Eq3	4.39	2.12	91.20	2.29	11.44	8.03	77.62	2.91								
Eq4	0.35	0.24	2.71	96.70	5.40	2.82	26.57	65.21								

Generalized value is 83.84%. This is true also in the shorter period: 94.77% vs. 93.82%. In the case of FR, the whole period the Cholesky-based FEVD contribution of CPI is 87.88% while the Generalized value is 84.64%. This is true also in the shorter period: 67.77% vs. 67.21%.

These results suggest that: (i) the generalized decomposition tends to overestimate the transmission mechanism and (ii) the CPI channel seems more active compared to the other two channels.

Third, considering the own FEVD contribution of the oil price variables, I find a group of countries with lower values below 50% for at least one, like the AU, JP, IT, IN, the US, and ZA, while for the other countries the values are above. It is interesting to note that the highest values, above 70%, are registered for the two oil exporting countries, namely RU and SA. Oil prices rise as an important mechanism of transmission in these relevant countries even if for different reasons. In the case of RU, this is due to the relevant financial market crisis in 2008–2009 and to the Ukraine sanctions in 2014. In the case of AU confirms its nature of commodities-based country, given that international commodities highly affect the AU economy. In the case of BR, the high shock transmission is mainly related to institutional factors, such as political instability. For the other countries, the common reason refers to their characteristics of net importer of crude oil. Finally, SA suffers the lack of the government's policy of stabilization through the diversification of the production base.

Fourth, considering the own FEVD contribution of the XR variable, a group of countries with high own FEVD contribution, above 75% is found: AU, BR, CA, CN, FR, GR, JP, SA, and ZA. Among these we find countries with relatively more important currencies, like the Euro and the Yuan (for SA the explanation is that the local currency is strictly pegged to the USD) that are less affected by turbulence and consequently they act less as channel transmission.

6.2. *The volatility spillover analysis*

Regarding H4, the volatility spillover analysis is reported in Tables 7 and 8. The entry *i,j* for each country is the estimated contribution to the forecast error variance of variable *i* coming from innovations to variable *j*. These results are based on the previous VAR-X estimations with Generalized decomposition, so that the measures of total spillover are not sensitive to the choice of the ordering. For each country, Table 7 reports, two boxes showing the spillover estimated for both periods, the whole sample Jan 2010-Dec 2021 and the pre-Covid sample Jan 2010-Jan-2020. The off-diagonal column sums labeled contributions to others (C to O) and row sum labeled contributions from others (C from O) are the "to" and "from" directional spillovers, and the "from minus to" differences are the net volatility spillovers. In addition, the total spillover index (TSI) is reported in the lower right corner of the box for each country. This is approximately the grand off-diagonal column sum (or row sum) relative to the grand column sum including diagonals (or row sum including diagonals), expressed as a percentage. The volatility spillover analysis offers an approximated "input–output" decomposition of the total volatility spillover index. For instance, in the case of AU, in the full period, notice that for the price of oil from the ID the contribution from others is 17.96, while the contribution to others is 18.93; for the XR, the contribution from others is 7.14, while the contribution to others is 9.96; for the CPI, the contribution from others is 7.74, while the contribution to others is 8.21. There emerge different patterns of spillover effects among variables.

First, it is interesting to consider the pattern of the TSI, total (non-directional) volatility spillover, which is effectively a distillation of the various directional volatility spillovers into a single index. The appears in the lower right corner the following tables, indicating, on average across our entire sample, the percentage of volatility of the forecast error variance of the four variables that come from spillovers. It is interesting to note that the TSI is increasing in the whole period for CA, CN, FR, JP, RU, and ZA, indicating that in these countries the Covid shock has had a significant impact on the volatility of the variables considered. However, large industrial countries like GE, UK, and the US were experiencing a reduction in the overall volatility spillover.

Second, it is interesting to consider the magnitude of the index, focusing on the cases in which is above the threshold of 50%. An index above 60% denotes that a major portion of the forecast error is coming from spillovers. This occurs for CA, CN, GE, IT, RU, US, and ZA.

Most of these countries can be identified as large industrial economies. Thus, this result is not surprising, considering that these are countries, which share high interconnectedness of trade and high flexibility in economic relations. In other words, these economies appear to be characterized by a higher degree of connectedness of oil, competitiveness, and inflation.

Third, turning the attention to the directional spillovers, gross and net, (Table 8) i.e., the "contribution to others" and the "contribution

Table 7
Generalized volatility spillovers.

AU-Full/ Jan20	ID	MY	XR	CPI	C from O	ID	MY	XR	CPI	C from O	BR-Full/ Jan20	SA	US	XR	CPI	C from O	SA	US	XR	CPI	C from O
ID	7.04	14.26	1.39	2.31	17.96	12.42	11.56	0.34	0.68	12.58	SA	10.47	9.46	4.13	0.93	14.53	11.12	9.43	1.90	2.55	13.88
MY	17.68	5.40	1.02	0.91	19.60	9.47	15.30	0.13	0.10	9.70	US	9.26	13.79	1.77	0.18	11.21	9.18	14.99	0.37	0.46	10.01
XR	1.16	0.98	17.86	4.99	7.14	0.01	0.91	17.55	6.53	7.45	XR	5.60	0.87	18.37	0.15	6.63	0.88	1.52	22.56	0.04	2.44
CPI	0.09	0.11	7.54	17.26	7.74	0.13	0.23	1.27	23.38	1.62	CPI	10.22	0.28	6.46	8.05	16.95	0.14	0.58	4.08	20.20	4.80
C to O	18.93	15.34	9.96	8.21	TSI	9.61	12.69	1.74	7.31	TSI	C to O	25.08	10.61	12.36	1.26	TSI	10.21	11.53	6.35	3.05	TSI
C to O + Own	25.97	20.74	27.82	25.47	0.48	22.03	27.99	19.29	30.69	0.69	C to O + Own	35.56	24.40	30.73	9.31	0.51	21.33	26.52	28.90	23.25	0.69
CA-Full/ Jan20	SA	US	XR	CPI	C from O	SA	US	XR	CPI	C from O	CN-Full/ Jan20	SA	RU	XR	CPI	C from O	SA	RU	XR	CPI	C from O
SA	13.17	3.09	8.10	0.64	11.83	7.60	8.25	8.62	0.52	17.40	SA	15.96	8.66	0.34	0.04	9.04	13.77	7.88	0.43	2.91	11.23
US	8.73	6.81	9.35	0.12	18.19	8.18	9.15	7.28	0.39	15.85	RU	14.64	9.40	0.77	0.19	15.60	11.95	9.00	0.85	3.20	16.00
XR	4.89	0.26	19.60	0.25	5.40	4.55	1.97	16.38	2.10	8.62	XR	1.07	0.09	23.66	0.19	1.34	1.82	0.21	22.82	0.16	2.18
CPI	0.91	0.10	3.03	20.96	4.04	0.18	0.06	1.31	23.46	1.54	CPI	1.11	0.27	0.68	22.93	2.07	0.22	0.03	4.23	20.53	4.47
C to O	14.52	3.45	20.47	1.01	TSI	12.91	10.28	17.21	3.01	TSI	C to O	16.82	9.02	1.79	0.42	TSI	13.99	8.12	5.51	6.27	TSI
C to O + Own	27.70	10.26	40.07	21.97	0.61	20.51	19.43	33.58	26.47	0.57	C to O + Own	32.78	18.42	25.44	23.36	0.72	27.76	17.12	28.32	26.80	0.66
FR-Full/ Jan20	SA	RU	XR	CPI	C from O	SA	RU	XR	CPI	C from O	GE-Full/ Jan20	RU	NO	XR	CPI	C from O	RU	NO	XR	CPI	C from O
SA	3.00	17.05	0.35	4.60	22.00	7.03	14.31	0.90	2.75	17.97	RU	6.96	17.82	0.10	0.12	18.04	8.53	14.14	0.41	1.92	16.47
RU	3.12	16.21	0.37	5.30	8.79	13.84	7.73	0.63	2.80	17.27	NO	3.69	21.05	0.09	0.17	3.95	3.34	19.57	0.41	1.67	5.43
XR	0.61	4.27	19.32	0.80	5.68	1.72	1.01	21.68	0.59	3.32	XR	0.60	2.34	22.04	0.03	2.96	0.14	0.18	20.52	4.16	4.48
CPI	1.58	0.72	1.54	21.16	3.84	0.76	1.49	5.97	16.78	8.22	CPI	0.11	0.32	5.13	19.44	5.56	0.13	0.08	0.09	24.69	0.31
C to O	5.30	22.04	2.26	10.71	TSI	16.31	16.81	7.51	6.14	TSI	C to O	4.40	20.47	5.32	0.32	TSI	3.62	14.39	0.92	7.76	TSI
C to O + Own	8.30	38.25	21.58	31.87	0.60	23.34	24.54	29.19	22.93	0.53	C to O + Own	11.36	41.53	27.36	19.76	0.69	12.14	33.97	21.44	32.45	0.73
IT-Full/Jan20	RU	AZ	XR	CPI	C from O	RU	AZ	XR	CPI	C from O	IN-Full/ Jan20	IQ	SA	XR	CPI	C from O	IQ	SA	XR	CPI	C from O
RU	12.02	9.31	0.27	3.40	12.98	10.52	12.73	1.44	0.30	14.48	IQ	12.50	7.08	2.81	2.62	12.50	14.25	8.54	1.74	0.47	10.75
AZ	6.38	15.38	0.51	2.74	9.62	2.18	21.19	1.36	0.28	3.81	SA	6.15	13.19	2.32	3.34	11.81	10.40	12.53	1.38	0.69	12.47
XR	2.81	2.81	16.17	3.22	8.83	0.67	2.95	20.29	1.09	4.71	XR	0.26	1.43	13.32	9.99	11.68	0.24	1.42	13.85	9.50	11.15
CPI	0.90	0.15	5.28	18.67	6.33	0.45	0.80	4.61	19.15	5.85	CPI	0.12	0.62	3.54	20.71	4.29	0.09	0.53	4.96	19.43	5.57
C to O	10.09	12.27	6.05	9.35	TSI	3.29	16.48	7.41	1.67	TSI	C to O	6.53	9.13	8.67	15.96	TSI	10.72	10.48	8.07	10.66	TSI
C to O + Own	22.11	27.65	22.22	28.02	0.62	13.81	37.67	27.70	20.82	0.71	C to O + Own	19.03	22.32	21.98	36.67	0.60	24.97	23.01	21.92	30.09	0.60

JP-Full/ Jan20	SA	AE	XR	CPI	C from O	SA	AE	XR	CPI	C from O	KR-Full/ Jan20	SA	AE	XR	CPI	C from O	SA	AE	XR	CPI	C from O
SA	4.38	19.54	0.09	0.99	20.62	7.86	13.33	2.31	1.50	17.14	SA	18.24	6.35	0.28	0.13	6.76	18.51	4.31	2.05	0.13	6.49
AE	7.22	16.71	0.38	0.69	8.29	13.05	9.29	1.53	1.13	15.71	AE	16.61	7.33	0.07	0.99	17.67	14.11	9.17	1.65	0.06	15.83
XR	0.02	0.07	22.83	2.08	2.17	0.05	0.21	21.01	3.72	3.99	XR	2.02	0.79	11.98	10.21	13.02	0.86	0.19	16.24	7.71	8.76
CPI	0.35	0.08	11.05	13.52	11.48	0.35	0.11	12.27	12.27	12.73	CPI	0.01	0.19	2.52	22.28	2.72	0.02	0.34	4.39	20.26	4.74
C to O	7.59	19.69	11.51	3.76	TSI	13.45	13.65	16.11	6.36	TSI	C to O	18.65	7.34	2.87	11.32	TSI	14.98	4.84	8.09	7.91	TSI
C to O + Own	11.97	36.40	34.34	17.28	0.57	21.31	22.94	37.12	18.63	0.50	C to O + Own	36.88	14.67	14.85	33.60	0.60	33.49	14.01	24.33	28.17	0.64
RU-Full/ Jan20	CN	NL	XR	CPI	C from O	CN	NL	XR	CPI	C from O	SA-Full/ Jan20	CN	JP	XR	CPI	C from O	CN	JP	XR	CPI	C from O
CN	17.68	6.25	0.07	1.00	7.32	12.05	12.02	0.13	0.80	12.95	CN	3.47	20.61	0.31	0.62	21.53	12.01	9.51	2.78	0.71	12.99
JP	11.51	12.49	0.06	0.95	12.51	9.71	14.37	0.17	0.75	10.63	JP	7.92	15.78	0.36	0.94	9.22	4.30	13.95	5.26	1.49	11.05
XR	3.79	4.52	16.05	0.64	8.95	3.90	6.34	14.45	0.31	10.55	XR	0.84	2.12	21.07	0.97	3.93	0.44	0.63	23.11	0.82	1.89
CPI	3.24	3.38	0.87	17.51	7.49	2.63	3.96	0.50	17.91	7.09	CPI	9.13	3.61	5.35	6.92	18.08	13.19	2.55	1.59	7.67	17.33
C to O	18.54	14.15	0.99	2.59	TSI	16.24	22.33	0.80	1.85	TSI	C to O	17.89	26.34	6.02	2.52	TSI	17.94	12.68	9.63	3.02	TSI
C to O + Own	36.22	26.63	17.05	20.11	0.64	28.29	36.70	15.25	19.76	0.59	C to O + Own	21.35	42.12	27.09	9.43	0.47	29.95	26.63	32.74	10.69	0.57
UK-Full/ Jan20	NO	NG	XR	CPI	C from O	NO	NG	XR	CPI	C from O	US-Full/ Jan20	CA	KR	XR	CPI	C from O	CA	KR	XR	CPI	C from O
NO	2.28	18.78	2.55	1.39	22.72	13.38	9.78	1.09	0.75	11.62	CA	10.96	3.18	5.51	5.35	14.04	10.85	0.59	11.65	1.92	14.15
NG	6.07	15.04	1.65	2.24	9.96	13.69	9.62	1.00	0.68	15.38	KR	2.18	13.16	5.03	4.64	11.84	3.72	8.42	11.12	1.73	16.58

(*continued on next page*)

Table 7 (*continued*)

JP-Full/Jan20	SA	AE	XR	CPI	C from O	SA	AE	XR	CPI	C from O	KR-Full/Jan20	SA	AE	XR	CPI	C from O	SA	AE	XR	CPI	C from O
XR	0.45	5.63	4.33	14.59	20.67	0.57	0.58	21.32	2.53	3.68	XR	0.13	0.97	12.14	11.76	12.86	1.25	3.17	17.81	2.76	7.19
CPI	0.22	2.85	0.84	21.09	3.91	2.51	2.81	8.94	10.75	14.25	CPI	0.32	2.77	2.18	19.73	5.27	0.05	0.13	0.58	24.23	0.77
C to O	6.74	27.26	5.04	18.23	TSI	16.76	13.17	11.02	3.96	TSI	C to O	2.63	6.92	12.72	21.75	TSI	5.02	3.89	23.35	6.41	TSI
C to O + Own	9.02	42.30	9.37	39.32	0.43	30.15	22.80	32.34	14.71	0.55	C to O + Own	13.58	20.08	24.86	41.48	0.56	15.87	12.32	41.16	30.64	0.61
ZA-Full/Jan20	AN	NG	XR	CPI	C from O	AN	NG	XR	CPI	C from O											
SA	11.06	13.74	0.03	0.17	13.94	11.32	12.91	0.05	0.72	13.68											
NG	13.74	11.15	0.01	0.10	13.85	14.20	9.66	0.07	1.06	15.34											
XR	1.10	0.53	22.80	0.57	2.20	2.86	2.01	19.40	0.73	5.60											
CPI	0.09	0.06	0.68	24.17	0.83	1.35	0.70	6.64	16.30	8.70											
C to O	14.92	14.33	0.71	0.84	TSI	18.41	15.63	6.76	2.51	TSI											
C to O + Own	25.98	25.49	23.51	25.02	0.69	29.73	25.29	26.17	18.81	0.57											

from others", different patterns can be identified, comparing the two periods of estimation. A relevant pattern is the coherent difference between periods: the index "To" and "From" are both higher in the second period for (at least one of) the oil variables for AU, BR, GE, and KR. For instance, considering AU, the index "To" for oil import from Indonesia is 18.93 in the whole period and is 9.61 in the pre-Covid period. The corresponding indexes "From" are equal to 17.96 and 12.58, respectively. In the opposite situation, we find large economies such as the UK and US with very low and substantially stable indexes "to" and "from" for the oil variables. Moreover, we find a general increase for the "to" and "from" contributions of the Exchange rate variable for most of the countries and an increase in both indexes in the CPI in AU, IT, RU, and the US.

Fourth, let us turn the attention to the cases when the pattern between periods is not coherent. A first case is the combination of the index "From" increasing and "To" decreasing, in the whole period: for the (at least one) variable of oil in CA, CN, IT, RU; the variable XR in Fr, IT, UK and the US; the variable CPI for BR, CA, SA. A second case is the reverse direction, i.e., the combination of the index "From" decreasing and "To" increasing, in the whole period (Table 8, panel a and b): for the (at least one) variable of oil in FR, GE, IN, JP, SA, UK and SA; the variable CPI for FR, IN, KR. These results show the importance of considering the bilateral spillover patterns and not only the total effect.

Fifth, a summary of the analysis of the "net transfer" defines a general picture of which variables act as transmitters or as receivers. Notice that both oil variables are a net transmitter in both periods for SA, RU and ZA, net receiver in both periods for IN and, US. For other countries, at least one oil variable is a net transmitter and it's noteworthy that this is the case when the oil supplier is SA and RU; for instance, in the case of BR, CA, and KR, the oil variable from SA is a net transmitter, and in the case of FR the oil variable for RU is also a net transmitter. The XR variable is a net transmitter for most of the large countries and more so in the whole period. In addition, notice that CPI is a net transmitter for many larger countries, such as AU, FR, IT, IN, KR, UK, US, and ZA. The results for XR and CPI also confirm the importance of the role of the USD in this context.

7. Conclusions

In this paper, a novel analysis of the relationship between oil prices, exchange rate, and inflation for 15 major G20 countries at a monthly frequency has been conducted. The oil price of the first two main suppliers to each importing country and of the two main customers of each exporting country is used, thus providing a more accurate measure of the monetary value of the oil imported and exported in each country at the monthly frequency. The novelty of this framework is that it provides a new perspective on the relationship between oil prices and the important macro variables, namely, the real effective exchange rate and inflation in each country. The empirical results show that significant effects can be captured when analyzing the specific oil prices that are imported in each country and that the impact of the oil price changes is different depending on the direction of the changes and on the period. In addition, results show the relevant effects also in some important oil exporting countries.

The existence of some asymmetric contagion effects is empirically demonstrated and moreover, such effects are relevant only for some oil importing countries only for exchange rate and inflation, while the oil prices downfall has more effect on oil exporting countries as compared to oil importing countries and large countries as compared to small countries. In addition, the dynamic relationships among oil prices, exchange rates, and inflation exhibit some significant changes in the period after the Covid-19 shock.

A relevant contribution of the approach using two oil price variables is that: (i) at least one of the two is always significant in the explanation of the other variables; (ii) the oil price of SA, whether it is the first or the second supplier in importance, is always a net transmitter in the

Table 8
Generalized volatility index.

Y - variables	Country	full sample				pre-Covid				Y - variables	Country	full sample				pre-Covid			
		To	From	Net	Net transfer	To	From	Net	Net transfer			To	From	Net	Net transfer	To	From	Net	Net transfer
ID	AU	18.93	17.96	0.97	Yes	9.61	12.58	−2.97	No	SA	BR	25.08	14.53	10.56	Yes	10.21	13.88	−3.67	No
MY		15.34	19.60	−4.26	No	12.69	9.70	2.99	Yes	US		10.61	11.21	−0.60	No	11.53	10.01	1.52	Yes
XR		9.96	7.14	2.82	Yes	1.74	7.45	−5.71	No	XR		12.36	6.63	5.73	Yes	6.35	2.44	3.90	Yes
CPI		8.21	7.74	0.47	Yes	7.31	1.62	5.69	Yes	CPI		1.26	16.95	−15.69	No	3.05	4.80	−1.75	No
SA	CA	14.52	11.83	2.70	Yes	12.91	17.40	−4.49	No	SA	CN	16.82	9.04	7.78	Yes	13.99	11.23	2.76	Yes
US		3.45	18.19	−14.74	No	10.28	15.85	−5.57	No	RU		9.02	15.60	−6.58	No	8.12	16.00	−7.88	No
XR		20.47	5.40	15.07	Yes	17.21	8.62	8.58	Yes	XR		1.79	1.34	0.44	Yes	5.51	2.18	3.32	Yes
CPI		1.01	4.04	−3.03	No	3.01	1.54	1.47	Yes	CPI		0.42	2.07	−1.64	No	6.27	4.47	1.80	Yes
SA	FR	5.30	22.00	−16.70	No	16.31	17.97	−1.66	No	RU	GE	4.40	18.04	−13.64	No	3.62	16.47	−12.86	No
RU		22.04	8.79	13.25	Yes	16.81	17.27	−0.46	No	NO		20.47	3.95	16.53	Yes	14.39	5.43	8.97	Yes
XR		2.26	5.68	−3.42	No	7.51	3.32	4.19	Yes	XR		5.32	2.96	2.36	Yes	0.92	4.48	−3.56	No
CPI		10.71	3.84	6.87	Yes	6.14	8.22	−2.07	No	CPI		0.32	5.56	−5.24	No	7.76	0.31	7.45	Yes
RU	IT	10.09	12.98	−2.89	No	3.29	14.48	−11.19	No	IQ	IN	6.53	12.50	−5.97	No	10.72	10.75	−0.03	No
AZ		12.27	9.62	2.65	Yes	16.48	3.81	12.67	Yes	SA		9.13	11.81	−2.68	No	10.48	12.47	−1.99	No
XR		6.05	8.83	−2.78	No	7.41	4.71	2.70	Yes	XR		8.67	11.68	−3.02	No	8.07	11.15	−3.08	No
CPI		9.35	6.33	3.02	Yes	1.67	5.85	−4.18	No	CPI		15.96	4.29	11.67	Yes	10.66	5.57	5.09	Yes

Y - variables	Country	full sample				pre-Covid				Y - variables	Country	full sample				pre-Covid			
		To	From	Net	Net transfer	To	From	Net	Net transfer			To	From	Net	Net transfer	To	From	Net	Net transfer
SA	JP	7.59	20.62	−13.03	No	13.45	17.14	−3.69	No	SA	KR	18.65	6.76	11.88	Yes	14.98	6.49	8.49	Yes
AE		19.69	8.29	11.40	Yes	13.65	15.71	−2.06	No	AE		7.34	17.67	−10.33	No	4.84	15.83	−10.99	No
XR		11.51	2.17	9.34	Yes	16.11	3.99	12.12	Yes	XR		2.87	13.02	−10.15	No	8.09	8.76	−0.67	No
CPI		3.76	11.48	−7.72	No	6.36	12.73	−6.37	No	CPI		11.32	2.72	8.60	Yes	7.91	4.74	3.17	Yes
CN	RU	18.54	7.32	11.22	Yes	16.24	12.95	3.29	Yes	CN	SA	17.89	21.53	−3.65	No	17.94	12.99	4.95	Yes
NL		14.15	12.51	1.63	Yes	22.33	10.63	11.70	Yes	JP		26.34	9.22	17.12	Yes	12.68	11.05	1.63	Yes
XR		0.99	8.95	−7.95	No	0.80	10.55	−9.75	No	XR		6.02	3.93	2.09	Yes	9.63	1.89	7.74	Yes
CPI		2.59	7.49	−4.89	No	1.85	7.09	−5.24	No	CPI		2.52	18.08	−15.57	No	3.02	17.33	−14.31	No
NO	UK	6.74	22.72	−15.98	No	16.76	11.62	5.15	Yes	CA	US	2.63	14.04	−11.42	No	5.02	14.15	−9.13	No
NG		27.26	9.96	17.30	Yes	13.17	15.38	−2.20	No	KR		6.92	11.84	−4.92	No	3.89	16.58	−12.68	No
XR		5.04	20.67	−15.63	No	11.02	3.68	7.34	Yes	XR		12.72	12.86	−0.14	No	23.35	7.19	16.16	Yes
CPI		18.23	3.91	14.32	Yes	3.96	14.25	−10.29	No	CPI		21.75	5.27	16.48	Yes	6.41	0.77	5.64	Yes
AN	ZA	14.92	13.94	0.98	Yes	18.41	13.68	4.73	Yes										
NG		14.33	13.85	0.49	Yes	15.63	15.34	0.29	Yes										
XR		0.71	2.20	−1.49	No	6.76	5.60	1.17	Yes										
CPI		0.84	0.83	0.02	Yes	2.51	8.70	−6.19	No										

spillover decomposition for all importing countries and this characteristic is reinforced after the Covid crisis. This can be interpreted as an indication of the strengthening of the SA role, after the disagreement within OPEC in March 2020 about the production quotas. In addition, this analysis is important not only in highlighting the relevant differences in the spillover effect among countries, but also because it can suggest a future line of research on analysis of the evolution of the nexus and the spillover among the variables and for different countries for the period starting in February 2022, after the outburst of the Ukrainian war.

In conclusion, there emerge some policy implications. For exporting countries characterized by a low degree of economic diversification, policies aimed to differentiate the production base could improve market stability. To avoid large, fast variations in exchange rates and achieve the stability of currencies, the monetary authorities of the countries which are more affected by the oil price shocks could consider enacting stronger solutions to reduce the negative effects of the oil price shocks, such as reinforcing mutual financial international cooperation to reduce exchange rate risks. Another implication for inflation targeting monetary authorities, such as the European Central Bank, is that they should not need to contrast short run inflationary shocks, unless there is a period of positive contagion on inflation. In these cases, as the CPI is a net transmitter as revealed by the connected analysis, it is appropriate for the central bank to consider such shocks when shaping its monetary policy. In other words, the design of an optimal monetary policy must be characterized by the awareness that how the long run (or core) inflation reacts to oil price shocks depends largely on the strength of the shocks.

Appendix A. Appendix

A.1. Detailed tests

A preliminary analysis of cointegration confirms that validity of the empirical strategy, as (most of) the level variables are I(1) for CPI and XR, as shown by augmented Dickey and Fuller (1979) and Phillips and Perron (1988) tests for the level variables in Table A.1 at the 1% significance.

Table A1: Unit root tests ADF and PP - sample: 2010:1 to 2021:12.

Test/Country CPI	CPIIT	CPIJP	CPIRU	CPICA
ADF *(p-value)*	0.96	0.03	0.42	0.82
PP *(p-value)*	1.00	0.30	0.46	0.48
Test/Country CPI	CPIFR	CPIGE	CPIIN	CPIUK
ADF *(p-value)*	0.72	0.96	0.32	0.91
PP *(p-value)*	0.75	0.96	0.20	0.98
Test/Country CPI	CPIBR	CPIKR	CPISA	CPIZA
ADF *(p-value)*	0.05	0.96	0.25	0.27
PP *(p-value)*	0.68	0.79	0.19	0.28
Test/Country CPI	XRBR	XRCA	XRCN	XRFR
ADF *(p-value)*	0.16	0.90	0.71	0.23
PP *(p-value)*	0.20	0.74	0.81	0.20
Test/Country CPI	XRIN	XRIT	XRJP	XRKR
ADF *(p-value)*	0.25	0.11	0.63	0.87
PP *(p-value)*	0.25	0.13	0.74	0.68
Test/Country CPI	XRSA	XRZA	XRUK	XRUS
ADF *(p-value)*	0.75	0.39	0.62	0.56
PP *(p-value)*	0.82	0.40	0.66	0.45

Note that there is only one exception: the null hypothesis is confirmed for CPI for China at 1%, but not at the 5% only for the ADF test. In addition, Engle and Granger (1987) tests among the four variables for each country (oil prices, CPI and XR) confirm the existence of cointegration as reported in Table A.2, with all *p* values rejecting the null hypothesis of no cointegration. value.

Table A.2: Engle-Granger cointegration tests.

Country	test	p-value
AU	−7.20	0.00
CA	−4.59	0.06
BR	−5.04	0.01
CN	−5.75	0.00
FR	−5.28	0.00
GE	−6.68	0.00
IN	−5.37	0.00
IT	−5.59	0.01
JP	−5.72	0.01
KR	−5.39	0.01
RU	−5.86	0.00
SA	−6.41	0.00
ZA	−5.68	0.00
UK	−7.36	0.00
US	−5.48	0.01

A.2 The generalized VAR ordering for the spillover analysis.

The FEVD is computed in a generalized vector autoregressive framework that is invariant to the variable ordering, measuring both total and directional volatility spillovers (Diebold and Yilmaz, 2012; Diebold and Yılmaz, 2014). For each variable I analyze the forecast error variances according to the various system shocks. Lets $Y_t = \sum_{i=1}^{p} \phi_i Y_{t-1} + U_t$ a covariance stationary N-variable VAR(p) and $U_t \sim (0, \Sigma)$ a vector of independent and identically distributed disturbances I define $Y_t = \sum_{i=0}^{\infty} \phi A_i U_{t-1}$ the moving average representation with the $N\,x\,N$ coefficient matrices where A_i is the recursive component: $A_i = \phi_1 A Y_{i-1} + \phi_2 A Y_{i-2} + \ldots + \phi_p A Y_{i-p}$ (A_0 being an $N\,x\,N$ identity matrix and $A_i = 0$ for $i < 0$). Given the shock of Y_j*, to Yi* ($\forall\, j \neq i$ and for each i) I assess the fraction of the H- step-ahead error variance in forecasting Y_i distinguishing own and cross variance share as the fractions of the H-step-ahead error variances in forecasting x_i. Own variance is due to its own shock meanwhile cross variance is due to shocks to other variables (spillover). I define $\theta_{ij}^{g}(H)$ the KPPS H-step-ahead forecast error variance decompositions for H = 1, 2, …, N as:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(u_i' A_h \sum u_j\right)^2}{\sum_{h=0}^{H-1} \left(u_j' A_h \sum A_h' u_i\right)} \tag{A.1}$$

where Σ is the variance matrix for the error vector *U,* σ_{jj} is the standard deviation of the error term for the j^{th} equation, and u_i is the usual selection vector. The normalization of eq. A.1 is as follow:

$$\widetilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \theta_{ij}^{g}(H)} \tag{A.2}$$

I define the total volatility spillover index () as:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1\\ i\neq j}}^{N} \widetilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H)} \bullet 100 = \frac{\sum_{\substack{i,j=1\\ i\neq j}}^{N} \widetilde{\theta}_{ij}^{g}(H)}{N} \bullet 100 \tag{A.3}$$

This measure is the contribution to the total forecast error variance of spillovers of volatility shocks in each variable across the whole set of variables, that is the total volatility spillover intensity. Furthermore, I compute the two types of directional volatility spillovers: (i) spillover received by variable *i* from all other variables *j*; (ii) spillover transmitted by variable *i* to all other variables *j.* Decomposition of the total spillover receive C form:

$$S_{i.}^{g}(H) = \frac{\sum_{\substack{j=1\\ j\neq i}}^{N} \widetilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H)} \bullet 100 = \frac{\sum_{\substack{j=1\\ j\neq i}}^{N} \widetilde{\theta}_{ij}^{g}(H)}{N} \bullet 100 \tag{A.4}$$

Decomposition of the total spillover transmitted to any given source:

$$S_{.i}^{g}(H) = \frac{\sum_{\substack{j=1\\ j\neq i}}^{N} \widetilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ji}^{g}(H)} \bullet 100 = \frac{\sum_{\substack{j=1\\ j\neq i}}^{N} \widetilde{\theta}_{ji}^{g}(H)}{N} \bullet 100 \tag{A.5}$$

The net volatility spillover from variable *i* to all other variables *j* is the difference between the volatility received and transmitted that is*:*

$$S_i^{g} = S_{.i}^{g}(H) - S_{i.}^{g}(H) \tag{A.6}$$

The bilateral volatility spillover is the difference between the volatility shocks transmit C from variable *i* to variable *j* and those transmit C form *j* to *i* that is:

$$S_{ij}^{g}(H) = \left(\frac{\widetilde{\theta}_{ji}^{g}(H)}{\sum_{i,k=1}^{N} \widetilde{\theta_{i,k}^{g}}(H)} - \frac{\widetilde{\theta}_{ij}^{g}(H)}{\sum_{j,k=1}^{N} \widetilde{\theta_{j,k}^{g}}(H)} \right) \bullet 100 = \left(\frac{\widetilde{\theta}_{ji}^{g}(H) - \widetilde{\theta}_{ij}^{g}(H)}{N} \right) \bullet 100 \tag{A.7}$$

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107156.

References

Ahmed, A.D., Huo, R., 2020. Linkages among energy price, exchange rates and stock markets: evidence from emerging African economies. Appl. Econ. 52 (18), 1921–1935.

Badel, A., McGillicuddy, J., 2015. Oil Prices and Inflation Expectations: Is there a Link? The Regional Economist, Federal Reserve Bank of St. Louis, St. Louis.

Balcilar, M., Usman, O., 2021. Exchange rate and oil price pass-through in the BRICS countries: evidence from the spillover index and rolling-sample analysis. Energy 229, 120666.

Beckmann, J., Czudaj, R.L., Arora, V., 2020. The relationship between oil prices and exchange rates: revisiting theory and evidence. Energy Econ. 88, 104772.

Beckmann, J., Belke, A., Dubova, I., 2022. What drives updates of inflation expectations? A Bayesian VAR analysis for the G-7 countries. World Econ. 45, 2748–2765.

Bigerna, S., Bollino, C.A., Polinori, P., 2021. Oil import portfolio risk and spillover volatility. Res. Policy 70, 101976.

Black, R.A., Benzing, C., 1991. Exchange rates, energy prices, unemployment, money, and inflation. East. Econ. J. 17 (2), 189–198.

Caporin, M., Naeem, M.A., Arif, M., Hasan, M., Vo, X.V., Shahzad, S.J.H., 2021. Asymmetric and time-frequency spillovers among commodities using high-frequency data. Res. Policy 70, 101958.

Choudri, E.U., Hakura, D.S., 2001. Exchange Rate Pass-through to Domestic Prices: Does Inflationary Environment Matter? IMF Working Paper, WP/01/194.

Choudri, E.U., Hakura, D.S., 2006. Exchange rate pass-through to domestic prices: does the inflationary environment matter? J. Int. Money Financ. 25 (4), 614–639.

Conflitti, C., Cristadoro, R., 2018. Oil Prices and Inflation Expectations. Occasional Papers (Questioni di economia e finanza), Banca d'Italia, p. 423.

Darvas, Z., 2021. Timely Measurement of Real Effective Exchange Rates. Working Paper 2021/15, Bruegel. Available at. https://www.bruegel.org/publications/datasets/real-effective-exchange-rates-for-178-countries-a-new-database.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74, 427–431.

Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: predictive directional measurement of volatility spillovers. Int. J. Forecast. 28 (1), 57–66.

Diebold, F.X., Yılmaz, K., 2014. On the network topology of variance decompositions: measuring the connectedness of financial firms. J. Econ. 182 (1), 119–134.

Ding, S., Zheng, D., Cui, T., Du, M., 2023. The oil price-inflation nexus: the exchange rate pass-through effect. Energy Econ. 125, 106828.

Donayre, L., Wilmot, N.A., 2016. The asymmetric effects of oil price shocks on the Canadian economy. Int. J. Energy Econ. Policy 6 (2), 167–182.

Dungey, M., Fry, R., González-Hermosillo, B., Martin, V.L., 2005. Empirical modeling of contagion: a review of methodologies. Quantit. Finance 5, 9–24.

Edwards, S., 2000. Contagion. World Econ. 23, 873–900.

Engle, R.F., Granger, C.W., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica 55 (2), 251–276.

FED, 2021. 108th Annual Report of the Board of Governors of the Federal Reserve System. available at. https://www.federalreserve.gov/publications/annualreport/default.htm.

Garzon, A.J., Hierro, L.A., 2021. Asymmetries in the transmission of oil price shocks to inflation in the eurozone. Econ. Model. 105, 105665.

Garzon, A.J., Hierro, L.A., 2022. Inflation, oil prices and exchange rates. The Euro's dampening effect. J. Policy Model 44 (1), 130–146.

Goldberg, P.K., Knetter, M.M., 1997. Goods prices and exchange rates: what have we learned? J. Econ. Lit. 35 (3), 1243–1272.

Golis, P., Gkasis, P., Bellos, S.K., 2022. Dynamic spillovers and linkages between gold, crude oil, S&P 500 and other economic and financial variables. Evidence from the USA. North Am. J. Econ. Finance 63, 101785.

Hameed, Z., Shafi, K., Nadeem, A., 2021. Volatility spillover effect between oil prices and foreign exchange markets. Energ. Strat. Rev. 38, 100712.

Hashmi, S.M., Chang, B.H., Bhutto, N.A., 2021. Asymmetric effect of oil prices on stock market prices: new evidence from oil-exporting and oil-importing countries. Res. Policy 70, 101946.

International Monetary Fund (IMF) 2022. International Monetary Fund, IMF access to Macroeconomic and financial data. Available at: https://data.imf.org/regular.aspx?key=61545849 (last accessed: 10 December 2022).

Jia, Z., Wen, S., Lin, B., 2021. The effects and reacts of COVID-19 pandemic and international oil price on energy, economy, and environment in China. Appl. Energy 302, 117612.

Küçükefe, B., 2020. Estimation of relationship between inflation foreign exchange rates and oil prices in Tukey. In: Khoich, A., Alper, A.E., Eren, A.A. (Eds.), Perspective on Modern Economy. IJOPEC Pub, London, pp. 135–146.

Kumeka, T.T., Uzoma-Nwosu, D.C., David-Wayas, M.O., 2022. The effects of COVID-19 on the interrelationship among oil prices, stock prices and exchange rates in selected oil exporting economies. Res. Policy 77, 102744.

Levich, R.M., 1985. Empirical studies of exchange rates: Price behavior, rate determination and market efficiency. In: Jones, R.W., Kenen, P.B. (Eds.), Handbook of International Economics, vol. 2. North Holland, Amsterdam, pp. 979–1040.

Li, Y., Guo, J., 2022. The asymmetric impacts of oil price and shocks on inflation in BRICS: a multiple threshold nonlinear ARDL model. Appl. Econ. 54 (12), 1377–1395.

Lin, B., Su, T., 2020. Does oil price have similar effects on the exchange rates of BRICS? Int. Rev. Financ. Anal. 69, 101461.

Lütkepohl, H., 2005. New Introduction to Multiple Time Series Analysis. Springer Science & Business Media, Berlin-Heidelberg.

Malik, F., Umar, Z., 2019. Dynamic connectedness of oil price shocks and exchange rates. Energy Econ. 84, 104501.

Nasir, M.A., Leung, M., 2021. US trade deficit, a reality check: new evidence incorporating asymmetric and non-linear effects of exchange rate dynamics. World Econ. 44 (3), 818–836.

Nasir, M.A., Vo, X.V., 2020. A quarter century of inflation targeting and structural change in exchange rate pass-through: evidence from the first three movers. Struct. Chang. Econ. Dyn. 54, 42–61.

Nasir, M.A., Naidoo, L., Shahbaz, M., Amoo, N., 2018. Implications of oil prices shocks for the major emerging economies: a comparative analysis of BRICS. Energy Econ. 76, 76–88.

Oloko, T.F., Ogbonna, A.E., Adedeji, A.A., Lakhani, N., 2021. Oil price shocks and inflation rate persistence: a fractional Cointegration VAR approach. Econ. Anal. Policy 70, 259–275.

Pericoli, M., Sbracia, M., 2003. A primer on financial contagion. J. Econ. Surv. 17, 571–608.

Pesaran, M.H., Pick, A., 2007. Econometric issues in the analysis of contagion. J. Econ. Dyn. Control. 31, 1245–1277.

Philips, A.S., Akinseye, A.B., Oduyemi, G.O., 2022. Do exchange rate and inflation rate matter in the cyclicality of oil price and stock returns? Res. Policy 78, 102882.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75 (2), 335–346.

Stein, J., 1982. Monetarist, Keynesian and New Classical Economics. New York University Press, New York.

Sun, C., Zhan, Y., Peng, Y., Cai, W., 2022. Crude oil price and exchange rate: evidence from the period before and after the launch of China's crude oil futures. Energy Econ. 105, 105707.

Syzdykova, A., Abubakirova, A., Kudabayeva, L., Zhantayeva, A., Omarova, A., 2022. Asymmetric causality relationship between oil prices and inflation in BRIC countries. Int. J. Energy Econ. Policy 12 (3), 184–191.

United Nations (UN), 2022a. UN Comtrade Database. Available at: https://comtrade.un.org/ (last accessed 10 December 2022).

United Nations (UN), 2022b. UN/LOCODE Code List by Country and Territory. Available at: https://unece.org/trade/cefact/unlocode-code-list-country-and-territory (last accessed 21 August 2022).

Volkov, N.I., Yuhn, K.H., 2016. Oil price shocks and exchange rate movements. Glob. Financ. J. 31, 18–30.

World Bank (WB), 2022. World Bank opendata. Available at: https://data.worldbank.org/ (last accessed: 10 December 2022).

Zhao, L., Zhang, X., Wang, S., Xu, S., 2016. The effects of oil price shocks on output and inflation in China. Energy Econ. 53, 101–110.