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How to simulate international economic sanctions: A multipurpose index modelling illustrated with EU sanctions against Russia

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ABSTRACT

One of the main challenges economists must face while studying economic sanctions is to simulate them in their models faithfully. It seems extremely hard to achieve without a dedicated variable that precisely imitates coercive economic measures. Thence, this short paper aims to offer a framework for the construction of economic sanction indexes. Researchers can use our multipurpose index modelling to simulate economic punishment in their econometric models. If our work is framed within the Ukrainian crisis case and European economic sanctions against Russia, the method we provide can be used in any other case study. It is a great alternative to the standard use of dummy variables that witness sanctions' implementation and withdrawal. Additionally, our proposal allows calibrating the weight attributed to each sanction depending on its type, the sanction sender's ability to apply economic pressure, and the effect of time on sanctions' effectiveness. The first part of this paper details the methodology and the mathematical formalisation of our framework. It is used to build a sanction index that simulates sanctions against Russia during the Ukrainian crisis. The second part is an empirical study that compares our index to another one from the literature. Results reveal that our new sanction index witnesses the behaviour of sanctions more precisely, which leads to a stronger explanatory power. Moreover, it enhances the statistical significance of impulse-response functions generated by our SVAR models. Consequently, the framework for sanction index construction that is proposed in this paper successfully produced a reliable index that simulates the European Union's sanction against Russia in the Ukrainian crisis case.

1. Introduction

International economic sanctions are a common tool used by governments in order to assert their diplomatic will. There are many examples of the implementation of these coercive measures: Iran since its nuclear program became public, Cuba even if sanctions have been recently lightened, Venezuela regarding the "*Government of Venezuela's erosion of human rights guarantees, persecution of political opponents, curtailment of press freedoms, use of violence and human rights violations,* [...]" as stated in the Executive Order13692,[1] or Russia on the basis of events resulting from the Ukrainian Crisis. In the literature, a significant amount of work has been achieved. Hence,

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[1] U.S. Department of The Treasury, March 8, 2015. https://www.treasury.gov/resource-center/sanctions/Programs/Documents/13692.pdf.

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economic punishment has been studied since the 60s, see Galtung (1967), Doxey (1980), Georgano et al. (1971), Hufbauer et al. (1990a, 1990b), Pape (1997), Drury (1998), and so on. Hufbauer et al. (1990a, 1990b) built a consequent sanctions database that covers all cases of coercive measures from 1914 to 1990 (115 cases in total). Their key result is that economic sanctions over the studied period have a success rate of 33%. Nonetheless, this result has been tempered by Pape (1997), which performs a strong and robust criticism of their work, reducing the sanctions' success rate over the same period to 5%. From another perspective, coercive measures often have unpredictable effects that are, paradoxically, in the very interest of targeted countries. Let's mention Nureev and Petrakov (2016), which highlights the realisation of the *Giffen paradox*.[2] Moreover, the study of Jones and Whitworth (2014) shows that international sanctions have encouraged Russia to seek new partners, in order to be less dependent on Western ones. Thence, most authors agree on the fact that sanctions do not work. Therefore, it seems legitimate to focus on sanctions' effectiveness, as it might explain the incapacity of sanctions to reach their goal.

The effectiveness is here defined as the ability of the sanction sender to inflict economic pressure to his target Doxey (1980). A possible way to measure sanctions' effectiveness is to proceed with quantitative analysis. The econometric tool is a valuable help to measure sanctions' economic effects. Yet, econometric models used in the studying of sanctions are not numerous. Most of the time, economists use gravity models, see Feenstra et al. (2001), Hufbauer et al. (2003), Caruso (2003), Yang et al. (2004), *et cetera*. This tool is interesting as it allows us to appreciate changes in trade due to sanctions. To do so, diplomatic measures are modelled through a dummy variable equal to zero if sanctions are not implemented, and to one if sanctions are enacted. Then, historical data without sanctions are compared to data with sanctions. If this method reveals all changes that happened after the arrival of sanctions, it does not help to isolate variations that are only due to sanctions. Additionally, a dummy variable does not simulate the behaviour of sanctions, as it only signals when sanctions are implemented and lifted. What is happening in between, such as changes in their effectiveness, is not simulated. It also fails to render sanctions' economic ability (disability) to impact their target. These elements are major issues as they imply that all sanctions are treated equally in econometric models. Yet, each sanction has its own identity, which induces very specific features (the sending country, the target, its duration, its ability to inflict economic pressure, and so on.)

Notwithstanding the interest of gravity models, another kind of model seems to be more appropriate in the study of sanctions. Vector Autoregression models (SVAR, TAR, STAR, SETAR, and so on), offer a different and new approach. They allow us to measure the variation of one variable due to its past value, or to the past value of another factor. In other words, we are now able to isolate the economic impact of sanctions from other causes (inflation, oil price, and so on). This being said, it is important to bear in mind that this kind of model requires a proper modelling of sanctions. It means that one must, first of all, be able to transform these punitive diplomatic measures into algorithm. Secondly, it also means that results' robustness and reliability will mostly depend on sanctions algorithm. If it does not reflect the economic reality stemmed from these measures, the model will probably lead to biased results. Therefore, it is crucial to succeed in modelling sanctions, which can be achieved by using sanctions indexes.

If economic sanctions are a very complicated and challenging topic, attempting to measure their economic effects is an even more arduous task. To our best knowledge, Dreger et al. (2016) were the first who used a Vector autoregression model to study sanctions (followed by Bali (2018)). They succeeded in building a "Sanction Index" simulating the economic impact of diplomatic measures implemented during the Ukrainian Crisis. One year later, this index was updated by Kholodilin and Netšunajev (2019). Nonetheless, their index requires serious modifications in order to give a faithful and clear picture of reality. Hence, this paper offers a framework for the construction of economic sanction indexes. The index construction that is introduced here allows researchers to create case-specific indexes, which precisely simulate international economic sanctions. The very identity of each sanction is considered, and weight is attributed depending on its type. It is also possible to adjust sanctions depending on their ability to inflict economic pressure to their target. Finally, the effect of time on sanctions' efficiency is also integrated. Each researcher is thus able to calibrate its index depending on the studied case. It is expected that the integration of such indexes into SVAR models will help to capture sanctions' economic effects. If our work uses the Ukrainian crisis case and economic sanctions against Russia, our methodological framework can be used in any other case.

2. Mathematical formalisation

This part describes and compares the previous sanction index from Dreger et al. (2016) to our new sanction index. Thus, the previous index serves as a benchmark for assessing improvements brought by our framework. It is a crucial reference point that is required to start a serious and open introspective reflection on this very topical subject.

2.1. Previous composite index

Dreger et al. (2016) have established a sanction index for the Ukrainian crisis case. This index has been expanded in Kholodilin and Netšunajev (2019). This composite index is the aggregation of dummy variables over time. The dummy can be equal to one, two, or three, depending on the sanction type. Then, the dummy's value is weighted by the issuing country's share in the target's foreign trade. This index is not perfect, but it is the first to illustrate sanctions within the framework of vector autoregression models (to our best knowledge). However, although it simulates rather well the arrival of international punitive measures, its value either grows over incoming new sanctions or stagnates when sanctions are not implemented. As a direct consequence, it never decreases over time. This implies that the economic impact of diplomatic measures – that is the economic pressure applied on their target – is sustainable and

[2] The fact that the consumption of some goods can increase even though their price is rising.

invariable.

In such conditions, a sanction applied in September 2014 will impose – at least – the same pressure in September 2015, September 2016, *et cetera*. It seems that this status quo hardly reflects reality. In addition, this index does not treat sanctions independently from each other. A "bonus" or a "penalty" cannot be applied to one sanction without affecting another. *In fine*, it is also impossible to know which measure costs more to a country (e.g. what is the most effective between American and European sanction regimes?) Finally, the weight that is assigned to sanctions depending on their type does not seem ideal. The value is equal to one if the sanction is against a person, to two if the measure targets an entity, and to three if it targets an industry. It thus means that targeting an entire economic sector (such as the Russian oil industry) weights only three times more than a sanction against one individual person. If it is true that the calibration of these values is quite delicate, this weights choice seems to have a serious proportionality issue. For these reasons, it is essential to introduce a framework for the construction of sanctions' indexes. Thence, the next subsection details the construction of a new index that is able to more faithfully simulate effects of coercive measures.

2.2. New composite index

The new index is also the aggregation of sanctions over time. Yet, it has been decided to handle sanctions independently from each other. Each sanction has its own identity, which allows to specify its own parameters. This index is defined as:

$$S_{t,k} = \sum_i s_{t,k,i}, \tag{1}$$

with s a sanction of identity i, imposed by a country k in period t. By doing so, if one sanction varies or, if the economic pressure inflicted by the sanction changes, other sanctions will not be affected. Naturally, parameters defining a sanction identity are many, and authors had to focus on the more viable and workable ones. Thus, each sanction can be defined depending on its type, its ability to apply economic pressure, and its effectiveness over time. The following introduces these three parameters.

2.2.1. Sanction type

The first parameter that can be specified in order to define a sanction's identity is the sanction type. Is the coercive measure against an individual? A company? An entire economic sector? The idea behind this is that economic pressure applied by diplomatic measures depends on the sanction type. Indeed, a sanction targeting individuals will not have the same economic consequences as one that aims an economic sector. In the literature, this matter is examined through the concept of weak and strong sanctions. For example, Doxey (1980) gives assurance that in the case of strong sanctions, the sanctioned entity will tend to submit to the issuer's will. Thirty years later, Whang (2010) consolidates this thesis with a quantitative study based on game theory (through a Bargaining Game).

> "Strong sanctions significantly enhance the predicted probability of compliance, whereas weak sanctions do not" (Whang (2010), p. 572).

Nevertheless, measuring the degree of economic pressure applied by this or that type of sanction on a case-by-case basis is a long and difficult task – if not impossible. Moreover, there is no guarantee that the outcomes of such research would drastically change models' results. This is why it has been decided to use a heuristic to simulate the economic pressure inflicted, depending on the sanction's type. Thus, the sanction type parameter can be written as:

$$\alpha_{t,k,i}, \tag{2}$$

where $\alpha_{t,k,i}$ is a constant for which the value depends on the type of sanction, see Table 1. The value that is attributed to each type of sanction can be adjusted and should not be seen as permanent. As each sanction case is particular, it is coherent to assume that researchers will have to adjust these values when building their own index.

Table 1
Values of the "Sanction Type" parameter.

α Value	Description
0	Absence of sanctions
1	Sanction against an individual
10	Official announcement of sanctions
100	Sanction against a company
1000	Sanction against an economic sector
3000	Embargo

Note: Authors are well aware that these values are arbitrary. Yet, one must understand that it is a first proposal to allow us to expose the rest of our work to criticism. Meanwhile, it gives us a moment to make further simulations in order to find optimal values. The idea behind it is that since Alpha's values differ depending on each sanction case, researchers shall deduce these values on a case-by-case basis. That is, through a trial and error approach instead of arbitrary choices.

$$E = \{0, 1, 10, 100, 1000, 3000\}$$

$$\{\alpha_{t,k,i} | E(\alpha_{t,k,i})\}$$

As it is, the lowest value is zero and stands for the absence of sanctions. The highest value is three thousand and witnesses the effects of an embargo, as total economic embargoes are described as the most effective type of coercive measure in the literature, see Rowe (1999), Escribà-Folch (2010), *et cetera*.

2.2.2. The economic leverage

The second parameter is the economic leverage, which describes the ability of the sanction sender to apply economic pressure on its target. For instance, in Dashti-Gibson et al. (1997), it is clearly stated that the extent of trade linkages between the target and the sender partly determines the probability of success of a sanction. To assess this ability, two main components are considered. Firstly, the trade intensity between the sanction sender and its target:

$$A_{t,k,j} = \frac{T_{t,k,j}}{T_{t,j}}, \quad (3)$$

with $T_{t,k,j}$ the total exports of j to k, and $T_{t,j}$ country j total foreign trade. It is assumed that exports are beneficial to the considered economy, while imports are a burden. For this reason, only exports are accounted in $A_{t,k,j}$. Yet, it is also possible in some specific cases to see imports as vital resources for the country, since it might not be possible to obtain these goods otherwise. If so, $T_{t,k,j}$ could be the total exports and imports of j to k.

Therefore, $A_{t,k,j}$ defines the fact that if the sanction sender (k) and the target (j) do not trade with each other, it is highly unlikely that any punitive economic measures will be effective and $A_{t,k,j} \to 0^+$. On the contrary, if players have a strong trade relationship and $A_{t,k,j} \to 1$, sanctions will have the wherewithal to exert economic pressure. Thence, McLean and Whang (2010) clearly reveal that sanctions' probability of success increases when sanctions are imposed by the target's main trading partner.

Secondly, the weighting of foreign trade in the target's economy:

$$B_{t,j} = \frac{T_{t,j}}{Y_{t,j}}, \quad (4)$$

with $Y_{t,j}$ the GDP of country j. This component witnesses the fact that even if players do have a strong economic relationship (i.e. $A_{t,k,j} \to 1$), sanctions might remain poorly effective if the target's foreign trade accounts for a very small share of its economy ($B_{t,j} \to 0^+$). Oppositely, if the under-sanction country's economy highly depends on foreign trade ($B_{t,j} \to 1$), coercive measures have good prospects of success. Consequently, the economic leverage can be defined as:

$$\beta_{t,k,j,i} = A_{t,k,j} * B_{t,j}. \quad (5)$$

Thus, for the economic leverage to be fully effective ($\beta_{t,k,j,i} \to 1$), players must be in a strong trade relationship ($A_{t,k,j} \to 1$), and the target's economy must be highly dependent on foreign trade ($B_{t,j} \to 1$). Finally, the last important point to consider is that trade relationship integrated in equations (4) and (5) should focus on economic sectors under sanctions. Indeed, if the traded goods are not targeted by sanctions, coercive measures shall not be able to apply such a great economic pressure.

2.2.3. Time factor

The third and last parameter gathers unconsidered factors that have a negative effect on the economic pressure applied by punitive measures. It witnesses the effect of time on the economic pressure induced by a sanction. This fact is highlighted and demonstrated in Neuenkirch and Neumeier (2015). Moreover, an entire paper was dedicated to this, see "How Long Economic Sanctions Last" from Bolks and Al-Sowayel (2000). They examine 108 sanction cases and one of the conclusions that they reach is that:

> "While the focus of this examination is not on sanction success, there is an underlying logic that links these two outcomes: shorter episodes are associated with more success while longer ones typify failure."
>
> (Bolks and Al-Sowayel (2000), p. 242).

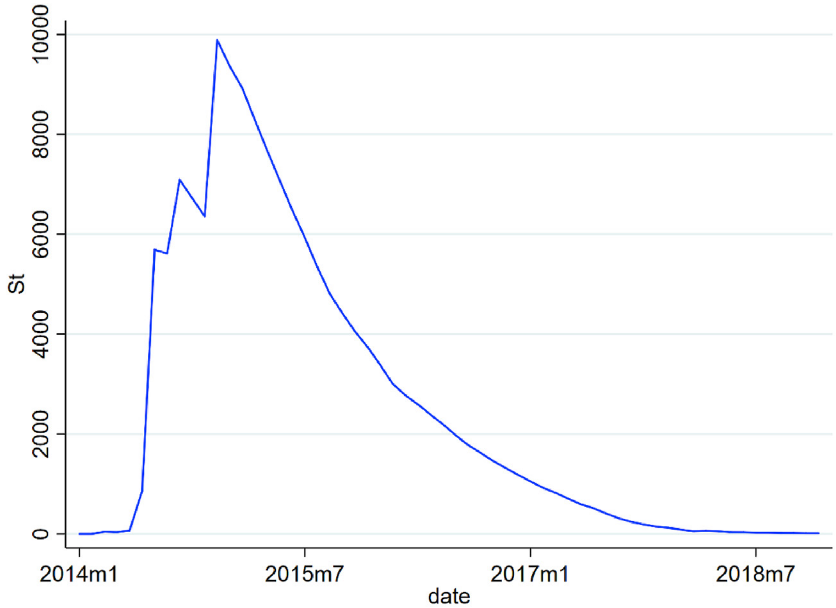
In Yang et al. (2009), it is also highlighted that the longer sanctions last, the more the target will export to third countries, which mechanically decreases the efficiency of coercive measures. Thus, the time factor reflects the fact that a penalty issued in t will not have similar economic effects in $t + 1$ or in $t + 20$, for example. In other words, it is the required time for an economy to adjust to sanctions. This parameter is written as:

$$\chi_{k,i,u} = \left(1 - \frac{u_{k,i}}{U_{k,i}}\right)^{o_{k,i}}, \quad (6)$$

where, k and i remain as defined before, but with u representing an instant from a different timeline than t. Indeed, while t is defined depending on the series' timeline (expressed in months, quarters, and so on), u is expressed in periods ($u \in \mathbb{R}$) and depends on the sanction's issuing date. It means that u can perfectly evolve independently from t. U is the ending date of the considered sanction i.

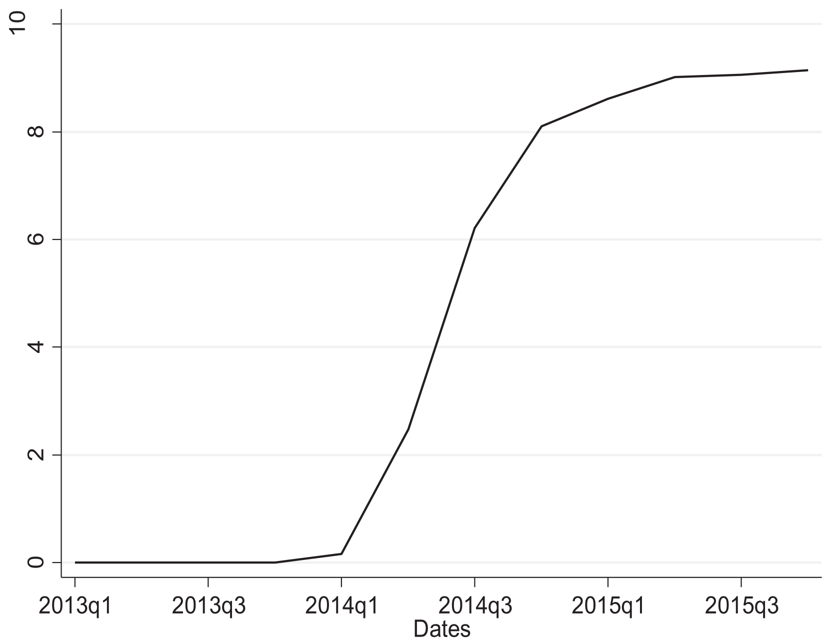
Finally, $o_{k,i}$ defines the slope of $\chi_{k,i,u}$. The lower $o_{k,i}$ is, the more horizontal the slope will be, and the less the time factor will negatively impact the sanction's ability to apply economic pressure. Reversely, the higher is the value of $o_{k,i}$, the more vertical the slope will be. In other words, $o_{k,i}$ is allowing us to calibrate the time factor intensity and behaviour (see Graphs 1 and 2).

When the sanction is implemented ($u = 0$), the economic pressure brought by the punitive measure is total and $\chi_{k,i,\ 0} = 1$. On the contrary, when the sanction's ability to inflict economic pressure is completely void, $\chi_{k,i,\ U} = 0$. Meaning that:



Note: The new sanction index is the sum (as explained in equation 7) of all European sanctions against Russia from March 2014 to March 2018. It is displayed in monthly frequency to reveal further details. Parameters' specification is available upon request.

Graph 1. New sanction index.



Graph 2. Previous sanction index.

$$\{\chi_{k,i,u} \in \mathbb{R} \mid 0 \leq \chi_{k,i,u} \leq 1\}$$

Naturally, $\chi_{k,i,u}$ and $o_{k,i}$ will be easier to calibrate in a past and ended sanction regime, than in a present case study – mostly because it will be possible to assess how fast sanctions have lost their efficiency over time. Reversely, if the sanction regime is not over at the time of studying, some arbitrary choices will need to be made. However, as each coercive measure is unique, this calibration will have to be done on a case-by-case basis, depending mostly on exogenous factors and results of statistical investigations. In the end, the new sanction index shall be equal to:

$$S_{t,k} = \sum_i s_{t,k,i} = \sum_i (\alpha_{t,k,i} * \beta_{t,k,j,i} * \chi_{k,i,u}) \tag{7}$$

3. Empirical analysis

The main objective of this section is to proceed to an empirical check of the new index, in comparison to the previous index of Kholodilin and Netšunajev (2019). In order to highlight differences between indexes, our main strategy is based on the use of SVAR models – mostly because they focus on effects of implemented idiosyncratic shocks through our endogenous variables across time. To be precise, results of orthogonalized impulse response functions (OIRFs) and variance decomposition of forecast errors (FEVD) will be studied to highlight differences between indexes. For consistency of comparison, four-country SVAR models based on the Ukrainian crisis case will be run, in order to assess sanctions impact on Russia's industrial prices.[3]

However, differences between sanction indexes will be studied in two distinct parts. Firstly, it will be done with two initial SVAR country models (A) and (B), regulated by two control variables, and secondly, through two extended SVAR country models (C) and (D), integrating this time two additional control variables. Through those econometric models, the overall effectiveness of the new approach is compared to the previous one. Be as it may, it is essential to understand that this empirical analysis is a kind of "sandbox" in which the framework that we previously introduced is tested. It gathers very simple models, with a variable choice that one could criticise. Yet, this has been done on purpose as we focus on changes brought by our index construction methodology. This is a first experiment for which the only goal remains to demonstrate the reliability of our sanction index modelling; the Ukrainian crisis case must be perceived as a mere illustration.

3.1. *Initial SVAR country model*

In this first SVAR modelling, two initial country SVAR models are run for purposes of studying dynamics of sanction indexes on industrial prices. Our goal is to demonstrate improvements brought by the new sanction index. To do so, a model (A) integrating the new sanction index will be compared to a model (B) that uses the previous sanction index. These models' OIRFs and FEVDs will be compared.

3.1.1. *Database*

To illustrate consequences of sanctions on the Russian industrial prices, data have been collected from January 2010 to July 2018 on a monthly frequency. Most of our variables are linearised except for the new and previous sanction index. Unit root tests have been done and show that our variables are stationary in first difference, except for the new sanction index that is stationary at levels.

1 *st*: New sanction index.
2 *d_sww*: Previous sanction index.
3 *dln_eru*: Real effective exchange rate (REER) – Russia, from the IMF.
4 *dln_oilp*: Brent oil price, from Intercontinental Exchange.
5 *dln_ipi*: Russian industrial price index, ROSSTAT.

3.1.2. *Model's frame*

As explained, two models are used in order to assess new features of our sanction index. According to the Cholesky ordering, our vector of endogenous variables is defined either as model (A) with the new sanction index, or as model (B) with the previous one.

$$y = (d\_st\ dln\_eru\ dln\_oilp\ dln\_ipi) \tag{A}$$

$$y = (d\_sww\ dln\_eru\ dln\_oilp\ dln\_ipi) \tag{B}$$

This paper follows the Cholesky identification method. In this identification, the ordering matters and depends on our assumptions. As a matter of fact, restrictive measures[4] of the European Union against the Russian Federation include restrictions on access to technologies related to the oil sector. Thence, it is assumed that international economic sanctions affect Russia's industrial prices negatively or positively. Moreover, Russia's petroleum industry has an important role in the country's industry and economy – see Kapustin and Grushevenko (2019) or Gustafson (2012). Furthermore, in some cases, it seems that changes in oil prices can directly affect

[3] Authors would have preferred to use GDP, but it is not expressed in monthly frequency.
[4] Commission Guidance Note on the implementation of certain provisions of Regulation (EU) No 833/2014.

industry-level prices, see Fukunaga et al. (2010). Thus, it is coherent to include oil prices in our models. Finally, as REER aims to assess countries' price competitiveness relatively to their principal competitors, it should have a proper place in our models. Consequently, it also assumed that sanctions might affect these two intermediary variables, which could in turn affect Russia's industrial prices. For these reasons, the causal ordering of variables will be:

$$d\_st \rightarrow dln\_eru \rightarrow dln\_oilp \rightarrow dln\_ipi \quad \text{(A)}$$

$$d\_sww \rightarrow dln\_eru \rightarrow dln\_oilp \rightarrow dln\_ipi \quad \text{(B)}$$

By doing so, sanction index is ordered first and acts as causal variable, meaning that it contemporaneously influences other variables without being impacted by them. The variable of interest is the industrial price index. It is affected by all variables without influencing them. The rouble real effective exchange rate and oil prices are control variables, as they have contemporaneous effects on our variable of interest. Finally, the optimal lag number for both models is two, as prescribed by results of the Akaike information criterion (AIC) test, Akaike (1998). Following the recommendations of Ivanov and Kilian (2005) regarding monthly VAR models, this test has been chosen over others (SBIC, HQIC, FPE).

3.1.3. New sanction index

Firstly, the analysis of impulse response functions shows that a positive shock of sanctions induces negative effects on rouble real effective exchange rate. These effects take place over the short-term and are introduced by the sanction index's restrictions. They may lessen the rouble's demand, and in turn depreciate it. Moreover, as the Russian economy is a commodity export-led economy, any negative REER variations should make oil or commodity production profitable, mostly as the combination of a transitory sanction shock and REER variation shall decrease oil price over the short-term. Finally, the sanction's shock has negative outcomes on Russian production as its negative effects last for up to three months after the transitory positive shock. From a statistical viewpoint, both REER and oil price variables react significantly to a positive shock of sanctions in the short-term.

Respectively, it happens during the first and second months for both variables, as confidence intervals do not include the zero line. It means that sanctions affect both variables negatively on the short-term. Nevertheless, results on our variable of interest are unclear. As previously noticed, a sanctions' shock has a persistent negative effect on Russia's industrial prices, even if not significant. This can mostly be explained by the economy adjustment hypothesis, based on both import-substitution strategy of Russia and changes in Russian international trade structure. For instance, regarding the replacement of foreign technologies, Russia had to turn to Asian partners such as China, Japan and South Korea, see Shagina (2018). Secondly, the Variance decomposition of forecast errors (FEVD) shows that the variability of endogenous variables follows OIRFs' main results, mostly as both REER and oil price variations over time are explained by sanctions' variations (respectively for 7.5% and 11.7%). Finally, results show that up to 5% of Russia's industrial prices variability over time is explained by the new sanction index. Yet, as noticed earlier on OIRFs results, sanctions do not affect the evolution of industrial prices effectively (see Table 2).

3.1.4. Previous sanction index

This subsection is dedicated to model (B), which is based on the previous sanction index. To get started, OIRFs' results reveal that general trends previously noticed in model (A) remain. Indeed, both REER and oil price react negatively to a transitory positive sanctions shock. Nevertheless, unlike previous results, REER and oil price suffer from a lack of significance. Regarding IPI, results show that a positive sanctions shock induces coherent consequences. Hence, it seems to affect industrial prices positively rather than negatively – over the short-term. However, as the previous index does not take into account the adaptability of the Russian economy, it appears that effects on variables last longer over time. Outcomes on oil price and REER continues from 5 to 6 months, and up to 5 months for IPI. Finally, FEVD results imply inconsistent outcomes through a reduction of explanatory power of sanction innovations on other variables variations. Indeed, only 4.4%, 4.1% and 0.6% are explained by fluctuations of the sanction index over time (respectively for REER, Oil price and IPI) (see Table 3).

Table 2
FEVD: Percentage changes of variables explained by the new sanction index.

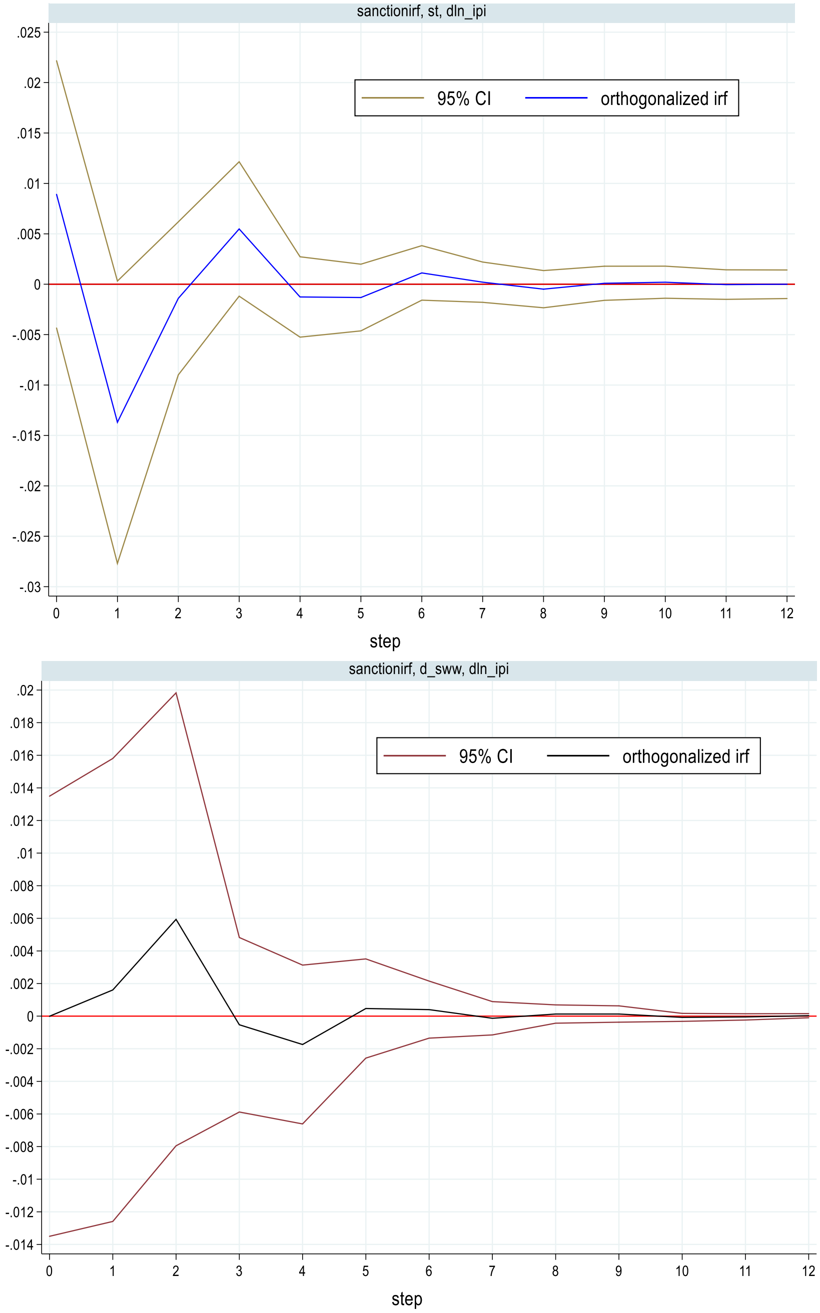
Variables	1 month	5 months	10 months	20 months
$reer_t$	7.0	7.0	7.2	7.5
$oilprice_t$	5.0	8.9	10.3	11.7
ipi_t	1.7	5.0	5.0	5.0

Table 3
FEVD: Percentage changes of variables explained by the previous sanction index.

Variables	1 month	5 months	10 months	20 months
$reer_t$	0.3	4.3	4.4	4.4
$oilprice_t$	0.0	4.1	4.1	4.1
ipi_t	0.0	0.6	0.6	0.6

3.1.5. Comparison

As our main goal is to compare outcomes on the most dependent variable (IPI) through models (A) and (B), comparison analysis focuses on both models' FEVD results. What do FEVD results say? It seems that using the new sanction index enhances models' explanatory power. For instance, sanctions in model (A) reach more than 5% of explanatory power, while sanctions in model (B) stand at less than 1%. This means that the new sanction index is able to justify the variations of industrial prices at least five times more than the previous sanction index. These results show that the new sanction index developed in this paper improves models' accuracy. To be precise, it affects IPI's variations on the short-term more sharply than the previous sanction index. In order to ensure the reliability of initial results regarding improvements brought by the new index, a second extended model is introduced in the next section (see Graph 3 and Table 4).



Note: Figures are the industrial price index implied responses to a sanction shock in model (A) –upper figure, and in model (B) –lower figure.

Graph 3. Orthogonalized Impulse Response Function, Comparison (A) vs (B).

Table 4
FEVD: Comparison between models A and B (percentage).

Steps/months	Impulse (st) Response (ipi) Model (A)	Impulse (sww) Response (ipi) Model (B)
1	1.7208	4.60E-07
5	5.0401	0.6945
10	5.0536	0.6966
15	5.0541	0.6967
20	5.0541	0.6967

3.2. Extended SVAR country models

Previous section allowed us to put forward key results regarding differences between the new and the previous sanction indexes. It is nonetheless important to run two additional models in order to confirm previous improvements. This section can be considered as a robustness test. Thus, two extended country SVAR models will be studied. Hence, model (C) and (D) are augmented by the arrival of two additional control variables: domestic capital flows and exports.

3.2.1. Database

Models developed in this section are based on previous implementations, with two additional control variables. In addition, period span and frequency remain as in the initial SVAR country model. Russian exports variable is linearised and turned in first difference to ensure stationarity, while capital flows are transformed in growth rates.

1 g_cf: Capital flows balance, as a growth rate for consistency purposes, from the Bank of International Settlements.
2 *dln_xru*: Russian exports, from ROSSTAT.

3.2.2. Model's frame

Adding two additional control variables naturally leads to a six endogenous variables country SVAR model. As before and for the same reasons, Cholesky decomposition ordering is used in this section. This time, our vector of endogenous variables is defined either as in model (C) with the new sanction index, or (D) with the previous sanction index.

$$y = (d\_st\ dln\_eru\ dln\_oilp\ dln\_xru\ g\_cf\ dln\_ipi) \tag{C}$$

$$y = (d\_sww\ dln\_eru\ dln\_oilp\ dln\_xru\ g\_cf\ dln\_ipi) \tag{D}$$

The ordering of endogenous variables follows the same logic as earlier. It is assumed that economic sanctions have an impact on Russian industrial price index. Two additional control variables are added in order to increase the robustness of our results.

$$d\_st \rightarrow dln\_eru \rightarrow dln\_oilp \rightarrow dln\_xru \rightarrow g\_cf \rightarrow dln\_ipi \tag{C}$$

$$d\_sww \rightarrow dln\_eru \rightarrow dln\_oilp \rightarrow dln\_xru \rightarrow g\_cf \rightarrow dln\_ipi \tag{D}$$

Thus, industrial price index is now contemporaneously impacted by sanctions (our causal variable), as well as four other control variables. It means that an impulse of sanctions with a response of industrial price index will include effects of REER, oil price, Russian exports, and capital flights. The optimal lag number for both models is still two, as prescribed by results of the Akaike information criterion (AIC) test, Akaike (1998).

3.2.3. New sanction index

According to OIRFs results, the introduction of two complementary variables leads to mixed results. Indeed, a transitory sanction's shock induces similar results as models (A) and (B). As previously discovered, a transitory shock of the new sanction index induces negative outcomes on REER and oil price over the period following the transitory shock. In addition, such a shock seems to negatively impact the complementary variables. Yet, Russian exports decrease more clearly over the short-term than capital flows. Moreover, capital flows are not effectively affected by sanctions. Finally, our variable of interest follows previous models' trends as OIRFs reveal that industrial prices react negatively to a sanctions' shock. Nevertheless, from a statistical perspective, it is vital to bear in mind that OIRFs results are significant for oil price and exports, but not for IPI (see Table 5).

The FEVD analysis shows important differences regarding endogenous variables' variability explained by the sanctions variable. Indeed, up to 6.6%, 11.2% and 4.8% of respectively REER, oil price and Russia's industrial prices variations are explained by sanctions. It means that the introduction of complementary variables reduces the explanatory power of sanctions.

Table 5
FEVD: Percentage changes of variables explained by the new sanction index.

Variables	1 month	5 months	10 months	20 months
$reer_t$	5.9	6.1	6.3	6.6
$oilprice_t$	5.2	8.5	9.9	11.2
$export_t$	0.2	4.4	4.8	5.2
$capflows_t$	0.2	0.4	0.5	0.5
gdp_t	1.0	4.7	4.8	4.8

Table 6
FEVD: Percentage change of variables explained by the previous sanction index.

Variables	1 month	5 months	10 months	20 months
$reer_t$	0.0	3.3	3.4	3.4
$oilprice_t$	0.0	3.7	3.9	3.9
$export_t$	0.0	3.7	3.6	3.6
$capflows_t$	1.2	3.8	3.8	3.8
ipi_t	0.0	0.6	0.7	0.7

Table 7
FEVD: Comparison between Model C and D (%).

Steps/months	Impulse (st) Response (ipi) Model (C)	Impulse (sww) Response (ipi) Model (D)
1	1.0724	0.0413
5	4.7352	0.6737
10	4.8014	0.7434
15	4.8015	0.7453
20	4.8018	0.7453

3.2.4. Previous sanction index

Regarding OIRFs, only oil price reacts significantly to a transitory positive shock of the original sanction index, while all remaining variables are not significant. The most dependent variable also shows coherent results as the transitory shock induces positive outcomes over the short-term. Yet, results regarding Russia's industrial prices also suffer from a lack of significance.

According to Table 6, two trends are emerging. Firstly, the introduction of complementary variables decreases the explanatory power of sanctions comparatively to models (A) and (B), especially for oil price and REER variables. Secondly, it is confirmed that results regarding the most dependent variable follow findings of model (B) – only 0.7% of the original sanction index explains variations of the industrial price index (in accordance with last section findings).

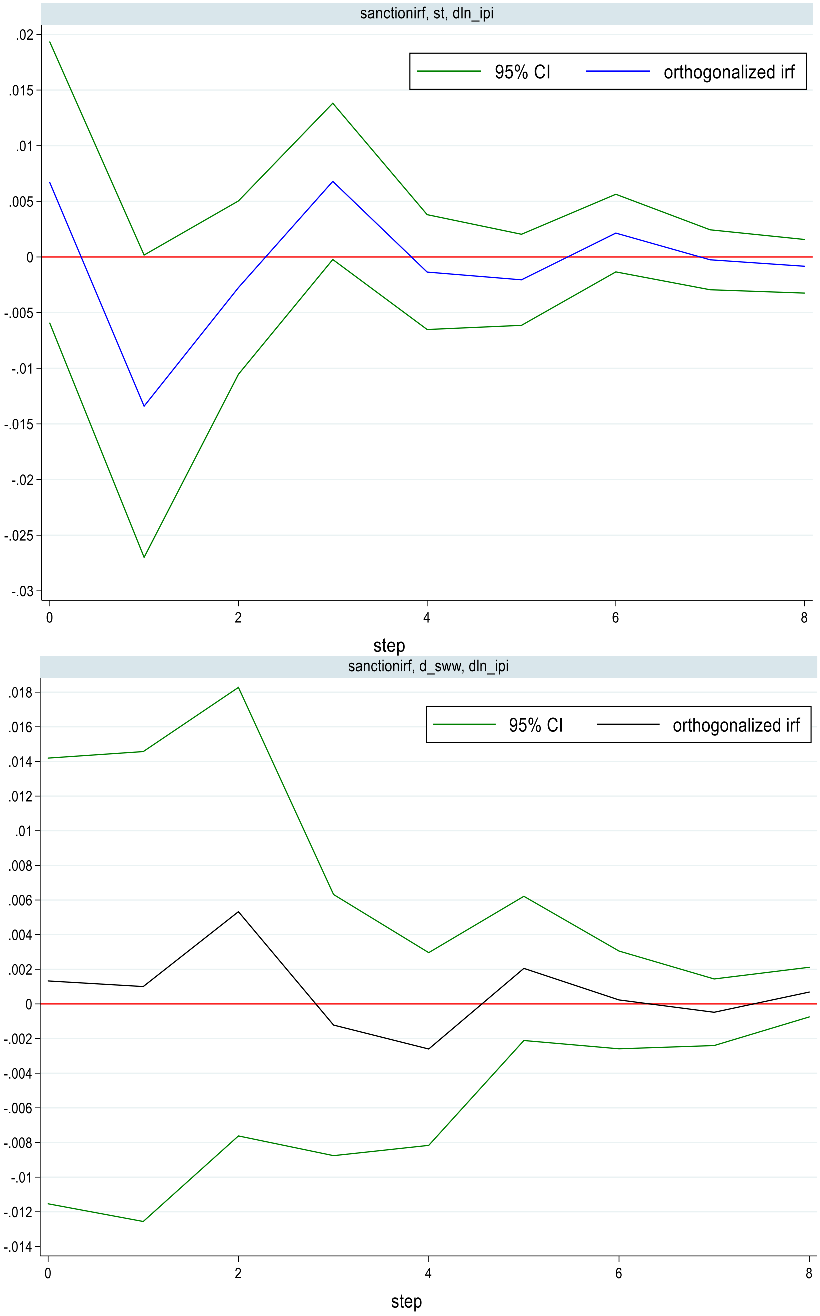
3.2.5. Comparison

According to FEVD results, model (C) has a stronger explanatory power than model (D). Indeed, while the new sanction index can explain 4.8% of industrial prices' variations, the previous one reaches 0.7%, reinforcing the new sanction index preponderance (see Graph 4 and Table 7).

4. Conclusion

The goal of this short paper is to offer a framework for the construction of economic sanction indexes. It is an attempt to obtain tools allowing researchers to simulate international economic sanctions in their econometric models. By doing so, it seems possible to catch the economic effects of international coercive measures. This work is framed within the Ukrainian crisis case and economic sanctions against Russia, but its methodology can be used in any other case. Thus, a new sanction index is offered and compared to a previous one, introduced in Dreger et al. (2016). It seems that the former index has three major issues. Firstly, sanctions' values do not integrate the effect of time on their effectiveness. The index will eventually stagnate when sanctions' implementation stops, but it cannot decrease over time. Secondly, sanctions are not treated independently from each other. It thus means that it is impossible to apply a special treatment to one sanction, without affecting other sanctions. Thirdly, the weight that is assigned to sanctions has a real proportionality issue. A sanction that targets an entire industry is equal to three sanctions that target a private individual. However, if these limits are major, it is still essential to bear in mind that this index is the first one that has been created – to our best knowledge, which is by itself a great step forward to the study of economic sanctions.

The new index that is developed in this paper proposes solutions to these issues. Nevertheless, it also has some limitations. If it is true that the proportionality issue is fixed, our alternative is also based on a heuristic. Ideally, future works shall deduce these values (i.e. values of the Alpha parameter) on a case-by-case basis. It can be done through a trial and error approach instead of arbitrary choices. Besides, our time factor seems hard to calibrate if the sanction episode is not over, or if it was recently implemented. It would be



Note: Figures are the industrial price index implied responses to a sanction shock in model (C) –upper figure, and in model (D) –lower figure.

Graph 4. Orthogonalized Impulse Response Function, Comparison (C) vs (D).

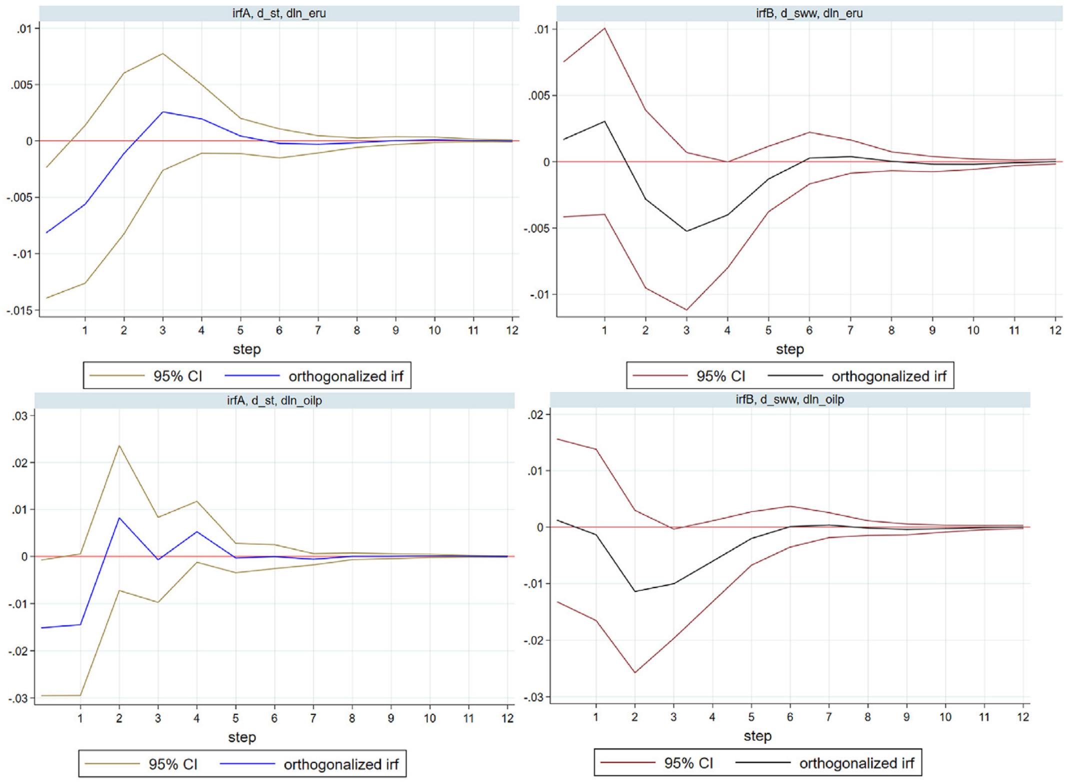
reasonable to encourage the testing of different scenarios and to observe their consequences. Finally, it is also essential to understand that this tool by itself is not enough to catch socio-political or socio-economic effects of sanctions. It seems to offer encouraging results through macroeconomic modelling, but similar outcomes are not guaranteed in other fields. Thence, our tool requires more work and authors are open to future contributions.

In order to assess improvements brought by the new sanction Index, four-country SVAR have been run. The first section "Initial SVAR Country Model" focused on four variables SVAR models. Sanction indexes as causal variable were ordered first, REER and Brent oil price were second (as control variables), and Russian industrial price index was last. Russian industrial price index was the most endogenous variable, and consequently the variable of interest. Model (A) was integrating the new sanction index, while model (B) used the previous sanction index. The second section "Extended SVAR country models" followed first section's structure but witnessed the arrival of two additional control variables: domestic capital flows and exports. It led to the run of models (C) and (D). The first one was using the new sanction index while the second one used the previous sanction index. That being said, results of the first section – with two control variables – reveal that the new sanction index has a four percentage points stronger explanatory power than the previous one. Also, it seems that our index affects short-term variations of industrial prices sharper than its predecessor. Improvements of the explanatory power are confirmed by the second section, supporting our index relevance.

Even if improvements made regarding variance decomposition of forecast errors are already a huge step forward, more can be said. For instance, the lack of significance illustrated by confidence-interval values – which could at first glance appear as a negative point, is a result by itself. It means that sanctions do not significantly influence IPI in the current models' configuration. It seems coherent to assume that additional control variables shall improve impulse response functions' significance. Hence, our study also emphasises that sanctions have a residual impact on industrial prices. As a consequence of the above, the framework for sanction index construction that is proposed in this paper successfully produced a reliable index that simulates the European Union's sanctions against Russia in the Ukrainian crisis case. We encourage its use and we will gladly share the index in other frequencies upon request. It is, however, important to bear in mind that it still has several limitations. Additionally, it is also valuable to remember that the framework that we introduced in this paper can be used to build other indexes. Future works have now the possibility to simulate coercive measures in their paper, even if it is not related to the Ukrainian crisis. One can perfectly use it to simulate American sanctions against Iran or Cuba, for example.

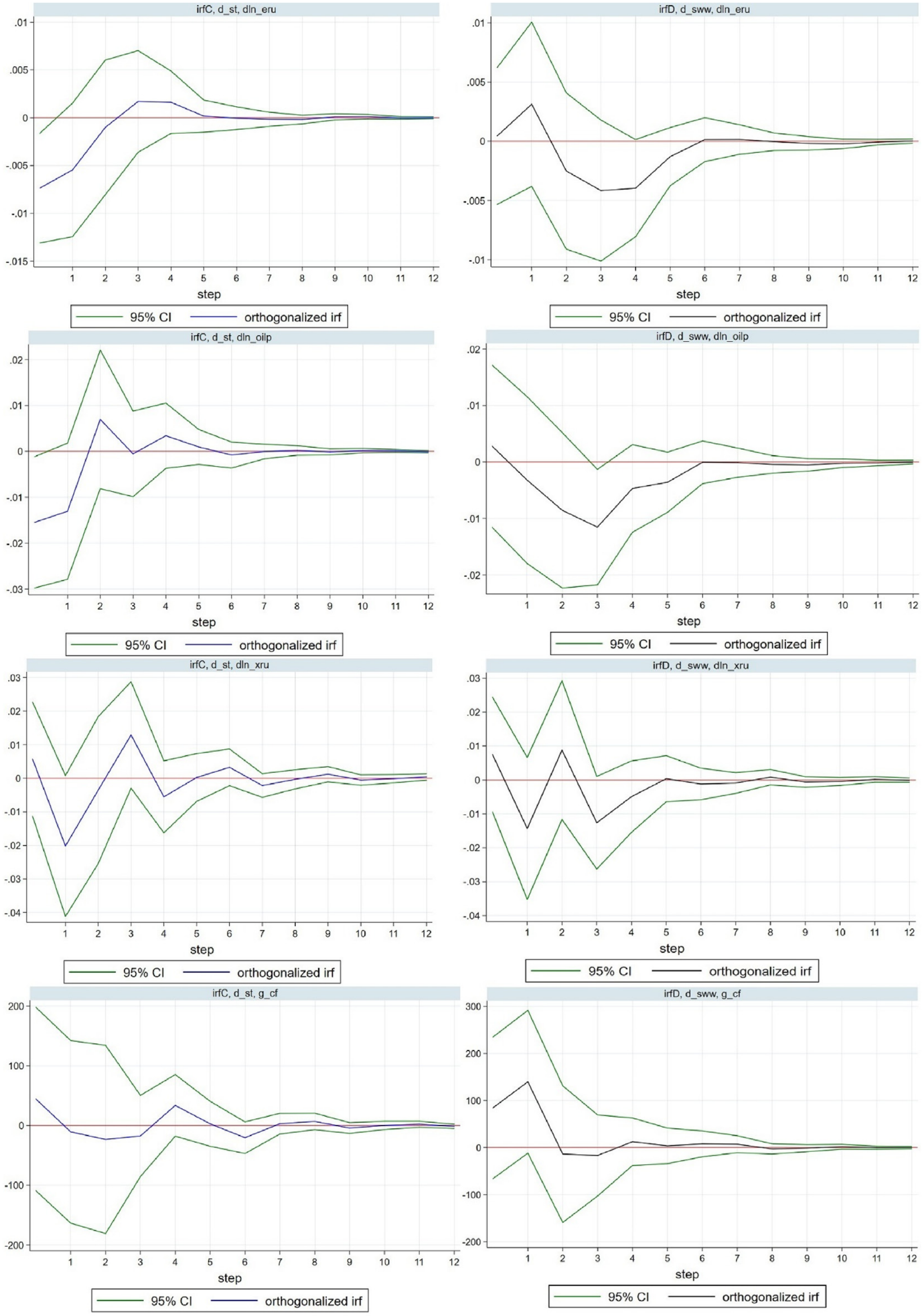
To conclude, it is essential to highlight the fact that, at the time of writing, irrespective of possible economic impacts, sanctions implemented in the Ukrainian crisis context do not work as they did not reach their political goal. Indeed, none of the involved players has changed its stance or own expectations regarding opponents' actions. On the one hand, the Republic of Crimea is still a subject of the Russian Federation and the situation in Eastern Ukraine remains unstable. On the other hand, the international community has not yielded to Russian countermeasures and embargo. Unavoidably, it is clear that both Western and Eastern measures are a diplomatic failure – future work could involve the use of political indicators to make a quantified assessment (Kauffmann, 2008, 2020; Kuperman, 2008).

Annexes



Note: Graphs of Model (A) are on the left, while Graphs of Model (B) are on the right.

ANNEX I. Orthogonalized Impulse-Response Functions, Model (A) and (B).



Note: Graphs of Model (C) are on the left, while graphs of Model (D) on the right.

ANNEX II. Orthogonalized Impulse-Response Functions, Model (C) and (D).

ANNEX III

Data Used for the New Sanctions Index

Dates	New sanctions index's values	Dates	New sanctions index's values	Dates	New sanctions index's values
2010m1	0	2013m7	0	2017m1	1048.72
2010m2	0	2013m8	0	2017m2	922.37
2010m3	0	2013m9	0	2017m3	820.91
2010m4	0	2013m10	0	2017m4	705.89
2010m5	0	2013m11	0	2017m5	594.59
2010m6	0	2013m12	0	2017m6	517.03
2010m7	0	2014m1	0	2017m7	412.05
2010m8	0	2014m2	0	2017m8	316.26
2010m9	0	2014m3	42.29	2017m9	242.64
2010m10	0	2014m4	33.9	2017m10	190.73
2010m11	0	2014m5	66.31	2017m11	145.17
2010m12	0	2014m6	859.26	2017m12	122.82
2011m1	0	2014m7	5691.14	2018m1	86.23
2011m2	0	2014m8	5615.26	2018m2	52.49
2011m3	0	2014m9	7090.49	2018m3	60.29
2011m4	0	2014m10	6722.84	2018m4	51.08
2011m5	0	2014m11	6359.19		
2011m6	0	2014m12	9888.54		
2011m7	0	2015m1	9365.03		
2011m8	0	2015m2	8926.36		
2011m9	0	2015m3	8294.5		
2011m10	0	2015m4	7672.33		
2011m11	0	2015m5	7074.26		
2011m12	0	2015m6	6480.26		
2012m1	0	2015m7	5931.04		
2012m2	0	2015m8	5341.02		
2012m3	0	2015m9	4804.72		
2012m4	0	2015m10	4418.26		
2012m5	0	2015m11	4055		
2012m6	0	2015m12	3744.65		
2012m7	0	2016m1	3389.33		
2012m8	0	2016m2	3010.38		
2012m9	0	2016m3	2782.31		
2012m10	0	2016m4	2595.97		
2012m11	0	2016m5	2388.09		
2012m12	0	2016m6	2193.91		
2013m1	0	2016m7	1980.24		
2013m2	0	2016m8	1780.53		
2013m3	0	2016m9	1623.34		
2013m4	0	2016m10	1460.89		
2013m5	0	2016m11	1319.56		
2013m6	0	2016m12	1181.77		

Note: As there is a need to limit the number of pages, the exact sanction list is available on request.

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