Where you export matters

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Abstract

Economic complexity theory deepens our understanding of export diversification. However, it relies on aggregated data which might disguise important details. In particular, these data do not take information on importers into account even though this information can provide new insights about the pace of economic complexity evolution in a particular economy. The paper introduces these new insights by incorporating more detailed export data into analysis. I find that wealthier economies not only tend to export more sophisticated products, but also sell them to richer destinations. I discuss the case of Russia which seeks to become a more complex economy and gain technological sovereignty by implementing reindustrialization policy. However, Russian complex products rarely conquer richer markets and are better known to Russia's geographic neighbors. Our findings suggest that such a pattern of reindustrialization might not be promising as long as a higher level of wealth is a concern. The paper claims that even though redesigning industrial policy such that it becomes more conditioned on export outcomes is not a solution to the problem, it is, however, one of its important ingredients.

Keywords: economic complexity, geographic diversification, Russia, import substitution.
JEL classification: F14, O33, O40.

1. Introduction

The surge in economic complexity literature (see Hidalgo, 2021) delivered a powerful analytical toolkit and structured argumentation (Hidalgo and Hausmann, 2009; Hausmann et al., 2014) which are used to study a variety of mechanisms linking the ability of a particular economy to produce complex products with an extensive list of phenomena and processes, such as income inequality (Hartmann et al., 2017; Zhu et al., 2020; Sbardella et al., 2017; Bandeira Morais et al., 2018, Fawaz and Rahnama-Moghadamm, 2019), human development (Ferraz et al., 2018, Lapatinas, 2016; Neagu, 2019) or greenhouse gas emis-

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sions (Neagu and Teodoru, 2019; Can and Gozgor, 2017, Lapatinas et al., 2019; Romero and Gramkow, 2021), to mention a few.

Economic complexity theory applies dimensionality reduction techniques to data on geography of economic activities, which helps making inferences on the location of economic output, such as export or employment. There is, however, at least one serious concern about the approach which lies at the core of the theory. The approach routinely relies on data, which contain information about the location and the type of economic output, but not about its recipients. As I argue below, the discussion of structural transformation (McMillan et al., 2016) might be richer if we also know who consumes this output and this could help construct a more sophisticated approach to estimate the level of economic complexity.

The argument is conceptualized in the following section. I then present an analytical approach and apply it to export data to derive my baseline results. As the Russian economy currently follows the process of reindustrialization, I discuss its prospects to illustrate the main findings.

2. The concept

To characterize changes which result from a shift in the production structure of a particular economy, Hausmann, Hwang and Rodrik (Hausmann et al., 2007), or HHR, introduced EXPY, a metrics of export sophistication. The metrics was designed to generate a signal whenever a country was becoming an exporter of a new product.

EXPY is introduced in two steps. At the first step, the value of exporting product p by economy c, which is denoted as x_{cp}, X_c, the total exports of country c, and Y_c, the level of GDP per capita, help construct the following indicator:

$$PRODY_p = \sum_c \frac{\frac{x_{cp}}{X_c}}{\sum_c \left(\frac{x_{cp}}{X_c}\right)} Y_c. \tag{1}$$

$PRODY_p$ provides a characteristic of product p, indicating whether richer or poorer economies, i.e. producing a larger or a smaller Y_c, are its main manufacturers. $\frac{\frac{x_{cp}}{X_c}}{\sum_c \left(\frac{x_{cp}}{X_c}\right)}$ is the index of revealed comparative advantage (see Balassa, 1965), which is used here as a weight assigned to Y_c. $PRODY_p$ suggests that more sophisticated products are typically exported by richer countries.

Since $PRODY_p$ is calculated for each p, one can derive an economy-wide characteristic $EXPY_c$, which is a weighted sum of all the relevant $PRODY_p$ values, each serving to characterize a product from economy c's export basket:

$$EXPY_p = \sum_c \left(\frac{x_{cp}}{X_c}\right) PRODY_p. \tag{2}$$

As is argued in HHR, a higher $EXPY_c$ is associated with faster economic growth. This might be because a successful transition to a higher level of product sophistication opens a door to a small club of complex products' manufacturers belonging to the global technological vanguard. They might reap higher

benefits resulting from a lower level of competition at the global market for a specific product.

However, $EXPY_c$ might not be an informative enough measure of product sophistication. It cannot distinguish between two different exporters in case they manufacture the same type of product. For instance, an automobile can be equipped with a wide arsenal of sophisticated technologies providing safer, more comfortable and greener driving, while another car can have none of that. Notwithstanding the difference between the two cars, it is not reflected in the export data which routinely classify both cars as automobiles.

However, as long as we agree that the difference between the aforementioned vehicles matters for automobilists, it should also affect manufacturers. A less financially constrained consumer would likely prefer a costlier, yet more advanced automobile as far as she is concerned about safety, comfort and cleaner air. Her preferences will probably be mirrored in the decisions of national bureaucracy, which might introduce barriers to eliminate less safe and environmentally unfriendly products from the national market.

It thus might be challenging to export a less sophisticated automobile to richer destinations. Therefore, joining the global club of car producers might not imply an exporting triumph. Instead, a newborn manufacturer can export its products to a small group of neighboring developing economies where consumers are less picky because their financial constraints are tighter. This might limit the opportunity of the manufacturer to reap higher benefits from scale economies.

Therefore, the geography of exports might contain important information about the level of product sophistication. A more technologically sophisticated producer might be able to export its goods to richer destinations than a less advanced one. The problem of $PRODY_p$ is that it fails to distinguish between the two. This might result in recurrent overestimation of growth prospects of less advanced producers.

To avoid this flaw, I disintegrate $PRODY_p$ into its geographic components. I follow Lyubimov and Iakubovskii (2020) and introduce an additional criterion while estimating whether an economy is or is not a competitive manufacturer of a particular product. Unlike the revealed comparative advantage approach (see Hausmann et al., 2014) which produces a marking of intensively exported products, I examine if an exported good is competitive enough at a specific geographic location. I then calculate a version of $PRODY$ using another definition of revealed comparative advantage, which takes exporters, products and importers into consideration. This approach allows to calculate a two-dimensional $PRODY$, which measures the average level of sophistication of a particular product imported to a specific geographic location.

In case a manufacturer exports its products to locations where an average competitor came from a poorer economy, and fails to compete with provisioners from richer places, I suggest that this might be an indication of a lower level of product sophistication. I then calculate $EXPY$ to see how firm is its association with per capita GDP and discuss the economy of Russia to illustrate my findings.

3. Method

In order to take the geographic destinations of exports into consideration, a slightly different version of the revealed comparative advantage index, RCA,

introduced in Balassa (1965), is suggested here. The original index is defined
as follows:

$$RCA_{c,p} = \frac{\frac{x_{c,p}}{\sum_c x_{c,p}}}{\frac{\sum_p x_{c,p}}{\sum_p \sum_c x_{c,p}}}. \tag{3}$$

The expression in (3) contrasts the role of economy c as an exporter of product
p with its contribution to the overall global exports. For instance, if c is, overall,
a microscopic exporter, but plays a more important role as a supplier of product p,
it is concluded that c has revealed comparative advantage in exporting p.

$RCA_{c,p}$, however, does not tell us which geographic locations contribute to
the high stance of country c as an exporter of product p. To disclose the geo-
graphic structure of c's exports, I complement $RCA_{c,p}$ with algebraically similar,
yet contextually distinct indicator:

$$RCA_{c,p}^z = \frac{\frac{x_{c,p}^z}{\sum_c x_{c,p}^z}}{\frac{x_{c,p}}{\sum_c x_{c,p}}}. \tag{4}$$

Here, z is an importing economy, and thus $RCA_{c,p}^z$ compares c's achievements
as an exporter of good p to country z with c's role as a global manufacturer of p. If
economy c's share in z's market of product p is larger than its overall importance
as a global supplier of p, we conclude that c has revealed comparative advantage
as a provisioner of product p to location z.

Finally, to capture information provided by both $RCA_{c,p}$ and $RCA_{c,p}^z$ in a single
value, let $RCA_{c,p}$ be multiplied by $RCA_{c,p}^z$ to obtain the following indicator:

$$RCA_{c,p,z} = \frac{\frac{x_{c,p}^z}{\sum_c x_{c,p}^z}}{\frac{\sum_p x_{c,p}}{\sum_p \sum_c x_{c,p}}}. \tag{5}$$

The index in (5) compares the role economy c plays in exporting product p to
destination z with c's overall stance as a global exporter. Whenever the former
is at least as large as the latter, I mark such a case with 1, otherwise I set it equal
to 0.

$RCA_{c,p,z}$ thus distinguishes between geographic markets where c is competitive
as an exporter of product p from locations where its role is modest, if not negligible.

The availability of detailed data on trade provides us with necessary inputs to
calculate the entire set of $RCA_{c,p,z}$. I organize the set as a three-dimensional array
$M_{Z,P,C}$, which is depicted schematically on Fig. 1, where indices Z, P, C represent
the length of each dimension.

I then construct a synthetic matrix $D_{C,P}$ by replicating P times a vector of real
per capita GDP levels for C economies, and perform a Hadamard multiplication
between $D_{C,P}$ and $M_{C,P,Z}$, a transposed version of $M_{Z,P,C}$. This step is implemented
to substitute each 1 in $M_{C,P,Z}$ with the relevant value of per capita GDP.

As a result, another three-dimensional array is obtained where each 1 from
the initial $M_{Z,P,C}$ array is replaced with the relevant value of GDP per capita. For
each pair of z and p I then calculate a matrix of average values of per capita GDP.
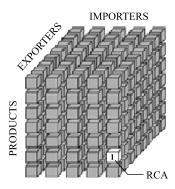
Fig. 1. Three-dimensional array $M_{Z,P,C}$, where indices Z, P, C represent the length of each dimension. i.e. the number of importers, products and exporters.

Source: Compiled by the author.

Algebraically, these steps can be articulated as follows:

$$PRODY_{Z,P} = \frac{\sum_C (M_{C,P,Z} \times D_{C,P})}{\sum_C M_{C,P,Z}}. \tag{6}$$

Each cell of matrix $PRODY_{Z,P}$ is a mean of per capita GDP values of all the economies supplying a specific product to a particular geographic destination.

Given $PRODY_{Z,P}$ and $M_{Z,P,C}$, one can perform another Hadamard multiplication to replace $RCA_{c,p,z}$ markers in $M_{Z,P,C}$ array with respective values from $PRODY_{Z,P}$ matrix. Another three-dimensional array which results from this multiplication, contains a corresponding $PRODY_{z,p}$ value for each combination of exporters, products and locations. The array is then used to calculate the mean value for each pair of p and c. Each mean value is associated with the average level of per capita GDP, thus telling us what kind of competitors — from poorer or richer economies — an economy c challenges when it starts exporting product p.

This result can be reproduced in the following expression:

$$EXPY_{C,P} = \frac{\sum_Z (M_{Z,P,C} \times PRODY_{Z,P})}{\sum_Z M_{Z,P,C}}. \tag{7}$$
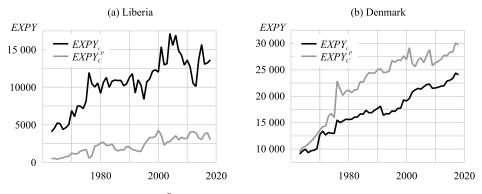
To characterize an exporter with a single value, I calculate $EXPY_C^P$, the average of $EXPY_{C,P}$ over P, the number of all exported products.

One can also calculate another version of *EXPY* by averaging the three-dimensional array, $M_{Z,P,C} \times PRODY_{Z,P}$, over goods instead of importers. Algebraically, this is done as follows:

$$EXPY_{C,Z} = \frac{\sum_P (M_{Z,P,C} \times PRODY_{Z,P})}{\sum_P M_{Z,P,C}}. \tag{8}$$

$EXPY_{C,Z}$ answers a different question: what kind of competitors, from richer or poorer locations, challenge a particular exporter at market z?

In this paper, I use $EXPY_C^Z$, which is the average of $EXPY_{C,Z}$ over Z, since, by taking a variety of geographical destinations of c's exports into account, it

Fig. 2. $EXPY_C^P$ and $EXPY_c$, Liberia and Denmark, 1962–2018.

Source: Compiled by the author.

emphasizes attaining broader geographic diversification and reaching more prosperous destinations as a mechanism of restructuring an export basket.

I use SITC 4digit data provided by the Atlas of economic complexity[1] for the period from 1962 to 2018 and the World Bank data on real per capita GDP for the same period, to calculate $PRODY_{Z,P}$ and $EXPY_C^Z$.

4. Main results

Let me start with a comparison between $EXPY_c$, which is introduced in HHR, and its 3D version, $EXPY_C^P$, which is determined in (5) above, to see if the latter systematically differs from the former.

In most cases, whenever poorer economies are considered, $EXPY_C^P$ is systematically lower than $EXPY_c$, while the opposite is true if richer economies are a concern. On Fig. 2 the economies of Liberia and Denmark illustrate this result.

The observed difference between $EXPY_C^P$ and $EXPY_c$ seems to be intuitive. HHR's $PRODY_p$, unlike $PRODY_{Z,P}$, does not distinguish between poorer and richer product markets. I.e. $PRODY_p$ is not designed to inform about the difference between a particular product market in a poorer economy and the same kind of market in a richer one. Instead, it aggregates geographical segments of the relevant market into a single global product market. Since poorer countries are important suppliers for their poorer geographic neighbors, relevant $PRODY_{Z,P}$ values are smaller and this results in $EXPY_C^P$ which is lower than its global average, $EXPY_c$. A symmetric argument provides an explanation why $EXPY_C^P$ is larger than $EXPY_c$ whenever a richer economy is considered.

That a poorer economy starts exporting more complex products thus does not necessarily imply that in response to this result economic growth is going to accelerate considerably. If new products reach only a few neighboring developing countries, the resulting economic return might be modest, which the negative gap between $EXPY_C^P$ and $EXPY_c$ indicates.

However, a small minority of economies do not follow the aforementioned pattern. For instance, for South Korea and India $EXPY_C^P$ and $EXPY_c$ more or less mimic each other and each such case requires a separate examination.

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[1] https://atlas.cid.harvard.edu/

I now turn to the discussion of $PRODY_{Z,P}$. Fig. S1, Supplementary material 1 uses a heatmap representation of 2018 data to visualize $PRODY_{Z,P}$. On the picture, countries are placed along the vertical axis, while products are positioned along the horizontal one. Darker shades of gray mark larger $PRODY_{Z,P}$ values, which are concentrated in the upper right part of the picture. This part consists of country-product pairs predominantly comprising rich economies, such as Denmark, Sweden or Germany, and complex products, such as "X-ray apparatus and equipment," "parts of the aircraft…," "measuring, controlling and scientific instruments," etc.

This implies that more prosperous economies not only produce more sophisti-cated products, but they also tend to export their products to richer destinations. Successful steps towards a higher level of product sophistication thus require building capacities to produce more complex goods, as well as to supply those products to richer locations, where consumers can afford purchasing brand new products based on cutting edge technology.

This suggests that, to be more informative, the structure of exports should reflect not only its product composition, but also its geographic component. The latter might be important for measuring the level of technological sophistication of a particular product. For instance, as it follows from 2018 data, such a product as "internal combustion piston engines, marine propulsion" is characterized by a much higher $PRODY_{Z,P}$ value when it is exported to Swedish or Irish markets, than to Tanzania or Kazakhstan.

Let me now turn to the phenomenon of "nestedness," which is discussed in Bustos et al. (2012) as a characteristic of production ecosystem. Bustos et al. (2012) argue that more complex ecosystems are capable to produce a larger va-riety of goods, both simple and complex. This implies that, ceteris paribus, they are equipped to export products which less complex ecosystems are also able to supply internationally. But the opposite is not true: poorer ecosystems cannot manufacture more complex output which more sophisticated ecosystems export.
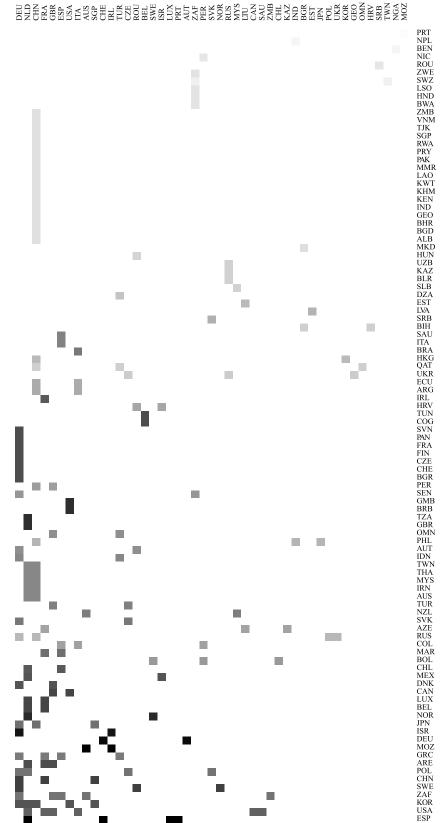
A similar reasoning might hold true not only for products, but also for geo-graphic locations: an ecosystem which is able to export a complex product to richer places, has sufficient know-how to export a similar product to poorer destinations, but the opposite might not be correct.

Fig. 3 is a heatmap which provides a detailed decomposition of $PRODY_{Z,P}$ for the product group "Rail locomotives, electric." It is clear that the leading producers of locomotives, such as Germany or China, are capable of exporting their products to a broad list of destinations, thus reaping more benefits from economies of scale. On the contrary, South Africa and Russia predominantly sell their locomotives to their geographical neighbors, thus having fewer opportuni-ties to exploit the advantages of scale economies.

A correlation diagram on Fig. 4 points at a high level of association link between per capita real GDP level and $EXPY_C^Z$. Fig. 5 also suggests that the geographic distri-butions of $EXPY_C^Z$ in 1962 and 2018 quite closely follow the ones of per capita GDP.

Since a more rigorous statistical analysis is beyond this paper's scope, here I conclude that a larger GDP per capita is associated with a higher level of $EXPY_C^Z$. Higher incomes go hand in hand with exporting more sophisticated products which reach more prosperous economies.

For a less developed economy to attain a higher level of economic complexity, it is important to implement steps which facilitate technological transfer from

Fig. 3. "Rail locomotives, electric" exporters and importers, 2018 data.

Note: The exporters are listed in rows, the importers are listed in columns.
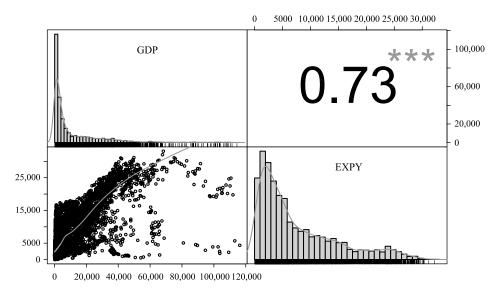
Source: Compiled by the author.

Fig. 4. Correlation between $EXPY_C^Z$ and GDP per capita, 1962–2018 SITC 4 digit data.

Source: Compiled by the author.
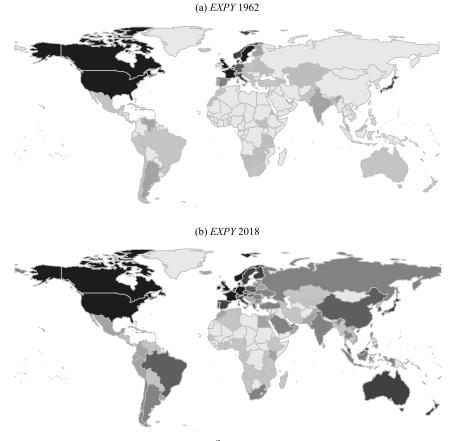
(a) *EXPY* 1962

(b) *EXPY* 2018

Fig. 6. $EXPY_C^Z$ in 1962 and 2018.

Note: A darker shade of gray is used to paint more prosperous countries and regions, such as Canada and Scandinavia, while light gray marks countries for which no data exist in the respective year.

Source: Compiled by the author.

a more advanced place. However, there are policies which successfully assist a transfer of technologies, but do not specifically target building broadly exporting industries afterwards, thus focusing on import substitution. These policies address the problem of insufficient production capabilities which are needed to manufacture a new product. But if the relevant policy does not provide powerful incentives to export new products intensively, the economy might fail to convert its increased economic complexity into broader export outcomes.

Thus, even if an economy attains a higher level of complexity, it might still stay relatively poor if it does not make sufficient efforts to broaden its exports. The economy of Russia might be at risk of following exactly this path, as it gives a priority to import substitution and is less focused on export goals.

5. Discussion: The case of Russia

The goal of gaining technological sovereignty had been articulated by the Russian authorities well before 2014, when strict sectoral sanctions limiting the availability of specific imports were imposed on the Russian economy. Reindustrialization was considered as a route towards sovereignty and, overall, as an important ingredient of economic modernization,[2] the view which was later echoed in studies discussing the problem of premature deindustrialization (Rodrik, 2016).

The policy of reindustrialization was intensified in response to sensitive sectoral sanctions which limited Russia's opportunities to acquire specific technologies and equipment (Connolly and Hanson, 2016). In his 2015 annual address to the Federal Assembly, Russian President Vladimir Putin emphasized that the process of import substitution should be accompanied by the emergence of an internationally competitive manufacturing sector:

> "*No one should fall for the illusion that under the guise of import substitution one can supply surrogates or stale goods at an exorbitant price to the state and citizens. Russia is in need of companies which are not only able to provision high-quality products internally, but can also conquer global markets*".[3]

At the same time, the respective industrial policy did not require explicitly that the state assistance had to be conditioned on attaining export goals. This point was also articulated by the leader of Russia in his 2015 address:

> "*...when programs of this kind were implemented in other economies, there were strict conditions imposed there to receive support from the state. It was required that a certain volume of products must be exported. What was that for? In order to encourage the production of high-quality goods. (But in our case) we are going to provide our own market (for national manufacturers). We have slightly different conditions to the economies which implemented those strict (pro-export) conditions.*"

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[2] http://www.vedomosti.ru/politics/news/1488145/o_nashih_ekonomicheskih_zadachah (in Russian).
[3] http://kremlin.ru/events/president/transcripts/messages/50864 (in Russian).

Following the address, specialized institutions were established in order to assist Russian exporters[4] and non-resource exports goals were determined and integrated into national strategic plans.[5] However, the policy did not prioritize developing a strong pro-export manufacturing sector. Export goals are positioned as important, but nonetheless peripheral, while the intention to attain product sovereignty seems to be the main goal of the reindustrialization policy.

Given such a policy design, one can expect that exporting complex products to richer destinations might be rare, so Russia's regional partners from the Eurasian Economic Union might ultimately become the main importers of its new exports.

This is what we observe so far if we focus on Russia's export details provided by the 3D-array, $M_{Z,P,C} \times PRODY_{Z,P}$. Russia exports a large variety of products, both more and less complex, but they largely reach its post-Soviet neighbors, such as Belarus, Kazakhstan, Armenia etc. (Fig. S2, Supplementary material 1). Its more geographically diverse exports prevailingly comprise less complex goods, such as "other wheat and meslin, unmilled," "kraft paper and paperboard, in rolls or sheets," "petroleum gases and other gaseous hydrocarbons, nes, liquefied," "petroleum products, refined," "mineral or chemical fertilizer, potassic," etc.

If this kind of export structure does not change over time, such that more complex products from Russia access richer markets, then it might be more difficult to reap higher economic benefits from the reindustrialization campaign. Russian manufacturers will keep modernizing their product lines and reaching a higher level of product sovereignty, but this achievement will not be translated into higher economic outcome.

An alternative design of industrial policy which emphasizes the importance of exports is definitely insufficient to change the current Russia's export structure. However, it might incentivize Russian manufacturers to export broadly and motivate the authorities to experiment with a variety of policy ingredients, which, if complemented with other policy ingredients, can ultimately pay off with better export results.

6. Concluding remarks

This paper claims that the economic complexity toolkit can become richer if a more detailed dataset is used to analyze exports. I suggest that taking data on importers into account to see what kind of markets—richer or poorer—an emerging exporter is able to reach, might give us a a better understanding of the true pace of economic complexity progress in the economy of interest. The paper finds that richer economies export more complex products and supply these products to wealthier destinations. I consider the case of Russia, which pursues the goal of gaining economic sovereignty and tries to make its economy more complex. So far, Russia's more sophisticated exports are more successful in the markets of its poorer geographic neighbors than at richer locations. It is suggested that redesigning industrial policy by making it more conditioned on export outcomes might contribute to the solution of the problem.

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[4] https://www.exportcenter.ru/en/
[5] https://www.russia-briefing.com/news/russia-s-non-energy-exports-up-to-30-of-gdp.html/

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Supplementary material 1

$PRODY_{Z,P}$ values, 2018 data

Author: Ivan Lyubimov

Data type: Image

Explanation note: Heatmap representation of $PRODY_{Z,P}$ based on 2018 data.

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Link: https://doi.org/10.32609/j.ruje.7.75423.suppl1

Supplementary material 2

The structure of Russian exports: products and destinations, 2018 data

Author: Ivan Lyubimov

Data type: Image

Explanation note: Heatmap representation of $PRODY_{Z,P}$ values for Russian exports, based on 2018 data.

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Link: https://doi.org/10.32609/j.ruje.7.75423.suppl2