Foreign Technology Transfer: An Assessment of Russia's Economic Dependence on High-Tech Imports

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Abstract

The article examines Russia's dependence on high-tech imported goods. We improve the OECD high-technology product classification by increasing the level of disaggregation, accounting for new goods, ensuring comparability over time, and differentiating goods by technological level on quite high levels of disaggregation. We describe the major trends in the world market for high-tech goods and identify the leading countries in each sector (most frequently, China, Germany, Republic of Korea, Switzerland, and Singapore) primarily by calculating net exports of high-tech goods in these sectors. We also assess Russian competitive positions in the global market for high-tech goods by sectors, applying the newly developed competitiveness index, and measure Russian dependence on high-tech goods imported from countries that recently imposed sanctions against Russia. We show that Russia's economy is highly dependent on imports of pharmaceutical goods and medical equipment, machinery and equipment (except nuclear reactors, fuel elements, engines and turbines), and electrical equipment. The sectors with most imports originating from 'sanction-imposing' countries are aircraft, medical and optical equipment, engines and turbines, and pharmaceutical goods. Computers and electronic equipment are at the opposite pole: in these sectors, China is the world leader and the key partner for Russia.

Keywords: hi-tech products; Russian external trade; technology and national security; global competition

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Technology Transfer through High-tech Imports

Research into international technology transfer peaked in the 1970s–1980s. As a general rule, scientific studies of the period focused on the relationship between research and development (R&D) and productivity in particular economic sectors or other indicators of technological development[1]. Nestor Terleckyj [*Terleckyj*, 1974] identified two types of impact R&D can have on productivity in industrial sectors[2]: a direct impact on a sector where R&D is taking place and an indirect impact on other sectors through the use of intermediate and investment goods from sectors where R&D is being conducted.[3] Terleckyj showed the relative strength of an indirect impact from R&D compared with a direct impact. Furthermore, in a similar analysis that Terleckyj carried out at a later date on non-industrial sectors, he demonstrated that the direct impact of R&D was extremely small and that the indirect impact was quite large [*Terleckyj*, 1980].

Frederic Scherer [*Scherer*, 1982] developed a matrix of technological processes in the US based on data on R&D carried out at 443 corporations representing 276 sectors and national patent activity. By breaking down R&D sectors of origin and use into internal and imported from other industries[4], he showed that the latter had a more pronounced impact on growth in productivity. However, the results were inconsistent. Within two years, more detailed research by Zvi Griliches and Frank Lichtenberg [*Griliches, Lichtenberg*, 1984] demonstrated that it was more R&D sector of origin than sector of use that had a positive impact on growth in productivity.

In the 1990s, a number of important studies were carried out in the US showing, on the one hand, that growth in productivity in sectors producing intermediate products has an impact on growth in productivity in those sectors which demand such products [*Wolff, Nadiri*, 1993]. On the other hand, based on statistics on the share of imports in GDP and total investment in R&D, it was shown that the total factor productivity of a country is heavily dependent on R&D investment in that country's trading partners [*Coe, Helpman*, 1995]. This result proved to be an important step towards empirical corroboration of technology transfer through goods imports.[5]

Specialists at the OECD Directorate for Science, Technology and Industry published an in-depth study on technology transfer through goods imports between 10 member states [*Papaconstantinou et al.*, 1996][6] which contains several interesting findings. First, R&D expenditure is predominantly concentrated in only a certain number of 35 sectors: the top five in which R&D is carried out account for between 60% and 80% of R&D expenditure, while the top five sectors which use R&D in the form of intermediate and investment goods make up only 40–50% of expenditure. Thus, the supply of high-tech goods is far more centralized than demand.[7] Furthermore, while demand varies by sector, technology supply predominantly originates in industrial sectors. Second, in seven of the ten OECD member states studied (Australia, Canada, Denmark, France, Italy, the Netherlands, and the United Kingdom i.e. not US, Germany and Japan), technology imports were more important than domestic R&D, which points to its value as a technology diffusion mechanism. Finally, the authors broke down imports into intermediate and investment goods and revealed the virtually equal importance of both channels with a slight advantage of the former.

As Wolfgang Keller [*Keller*, 2000] showed in his case study of eight OECD member states, unlike the typical country structure (from the perspective of the share of technological leaders), goods imports even have an impact on total factor productivity in developed economies. According to Keller's assessment, in view of the differences in imports structure, this effect is most pronounced in developing countries. His analysis also corroborated the fact that the productivity of OECD member states is more dependent on domestic R&D than foreign. He predicted the opposite for developing countries, with high-tech imports the main channel of technology transfer.

Similar studies were carried out for investment goods which showed that imports of investment goods play a greater role in technology transfer compared with intermediate and finished goods [*Xu, Wang*, 1999]. Subsequently, however, no consensus has been reached on these findings: different studies value investment and intermediate goods differently. A later approach examined the differentiation of the

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1 The level of technological development is most frequently taken to mean total factor productivity in a production function.

2 The idea of conceiving R&D as an additional factor of production alongside labour and capital was first formulated by Zvi Griliches [*Griliches*, 1973].

3 The input-output model was used to assess the indirect impact of R&D. Calculations have been carried out for the US economy.

4 For every single patent, the sectors of origin and expected use were identified, together with the cost of the R&D associated with the patent in US dollars, which was then distributed among the sectors of use, allowing a matrix resembling the input-output model to be formulated. The row total in the technological process matrices showed R&D sector of origin, the column total R&D sector of use, and diagonals R&D carried out and used in a single sector.

5 Imports of specific goods were not examined at the time, so the conclusions were derived exclusively by combining the factors 'share of imports in GDP' and 'total investment in R&D abroad' and were extremely general. However, this work was unique as it was one of the first to summarize data on a relatively large number of countries — 22.

6 Like in Terleckyj's work, to model the connections between economic sectors in OECD member states, the authors used the input-output model.

7 We note that this fact is fully in line with Terleckyj's findings described above on the stronger indirect impact of R&D on productivity.

capital structure (imported investment goods) in a production function as one of the most important sources of difference in the total factor productivity of countries [*Caselli, Wilson*, 2004].[8] It was shown that high-tech types of capital (computers, aerospace, communications and electrical equipment) can only be used effectively in countries that are developed from the perspective of human capital, the amount of foreign direct investment (FDI) and intellectual property rights protection.

Recent works have studied in greater depth the dependent relationship between the effectiveness of technology transfer through goods imports and the characteristics of a country [*Stone, Shepherd*, 2011]. Key parameters for intermediate goods are access to funding and a qualified work force, and for investment goods access to funding and macroeconomic stability.[9]

Imports as a channel for technology transfer have been examined alongside other factors in the academic literature, predominantly FDI. One of the first works devoted to goods imports and FDI as a channel for technology transfer [*Lichtenberg, van Pottelsberghe de la Potterie*, 1998] concluded that there was a weak effect on the productivity of incoming FDI, unlike outgoing, under high import volumes. This is also corroborated by subsequent studies [*Zhu, Jeon*, 2007; *Krammer*, 2014].[10]

Finally, there is evidence of a positive impact of high-tech goods imports on exports. Thus, imports of intermediate goods from OECD countries provoked higher export growth in Chinese businesses than imports from other countries. On the whole, imports of this category of goods had a greater effect from the perspective of export growth in sectors with high R&D intensity [*Feng et al.*, 2012]. This effect results from the growth in productivity, reduction in costs and local stakeholders gaining access to technologies clearing the way to foreign markets, all caused by imports of intermediate and investment goods [*Bas, Strauss-Kahn*, 2014].[11]

From the above literature review, we can draw several important conclusions:

- it would be sensible to limit the analysis of technology transfer to the main transfer channel of high-tech imports;
- high-tech intermediate and investment goods should be viewed together: there are no signs of a preference for either as channels for technology transfer;
- high-tech imports are an integral part of modern economies' foreign economic activity, especially in emerging economies. Thus, an inter-country comparison would be effective in determining dependence on imports;
- in order to adequately evaluate the current technological level of a sector, analysis needs to take account of the volume of both goods imports and exports.

Approaches to Classifying High-Tech Goods

To determine the technological level of a sector or product, three approaches are generally used in global practice.

1) *Industry sectors are ranked according to their technological level based on data on the ratio of R&D expenditure to added value or output.*

In the second version of the ISIC classification (International Standard Industrial Classification of All Economic Activities) in 1997, the OECD Directorate for Science, Technology and Industry proposed grouping economic sectors by technological level depending on the intensity of R&D expenditure, calculated as the ratio of R&D spending to added value [*Hatzichronoglou*, 1997]. Sectors were therefore divided into four groups: high-technology, medium-high technology, medium-low technology and low-technology. Later, in ISIC version three, sectors were grouped based on assessments of their R&D expenditure relative to the added value of the output and gross production volume. Under this variant, the make-up of the groups changed somewhat: the high-technology group included sectors such as aircraft production, office equipment and computer equipment, radio, TV and communications equipment, medical and precision instruments, and pharmaceuticals, and the medium-high-technology group covered other machinery and equipment not elsewhere classified (electrical machinery, motor vehicles and railroad transport) and chemicals, excluding pharmaceuticals [OECD, 2011].

2) *Industrial goods are ranked according to their technological level based on data on R&D expenditure per unit of output.*

Together with the German Fraunhofer Institute in 1994, the OECD Secretariat drafted a list of high-tech goods in line with the Standard International Trade Classification (SITC), version 3. Products were

[8] The capital structure in this model has an impact on productivity due to the fact that all nine types identified have different levels of effectiveness domestically. For the majority of developing countries, the authors note that imports of certain types of investment goods serve as a fairly accurate measure of the amount of investment in that type of equipment.

[9] World Bank business surveys are one source: country conditions are assessed through the perception of company directors. As expected, the importance of financial restrictions when importing investment goods has been confirmed by business data in India [*Bas, Berthou,* 2012].

[10] The importance of FDI has been confirmed, limited though it is. Factors such as the level of telephone communications [*Zhu, Jeon*, 2007] and non-resident patents in the country [*Krammer*, 2014] have also been studied.

[11] This channel could take the form of creating new goods never produced before in the country thanks to access to imported intermediate goods which had never been imported before [*Colantone, Crino*, 2014].

included in the list following an analysis of the relationship between R&D spending and product sales in six countries — the US, Japan, Germany, Italy, Sweden and the Netherlands [*Hatzichronoglou*, 1997]. Currently, the UN, OECD, Eurostat and statistical agencies in different countries use the fourth version of SITC (Table 1) to classify high-tech goods. Compared with the sectoral approach, where the technological level of a product is determined from the overall level of the sector as a whole, the 'product' approach allows for a far greater level of accuracy in evaluation.

3) *Patent applications are grouped by technology type.*

According to a report by the European, Japanese and US patent offices [Trilateral Patent Offices, 2007], the high-tech category covers patents in the following areas, in line with the International Patent Classification groups: computer and automated production equipment, aviation, genetic engineering, lasers, semiconductors, and communications technologies. To reflect these data in goods classifications by technological level, conversion tables are needed between patent classifications and product classifications. This is no trivial task and goes beyond the scope of this article.

The optimal classification of high-tech goods is the 2007 version of the Harmonized System (HS 2007) as it best satisfies the following requirements in terms of its convenience for practical use:

- accounting for new goods that have emerged in the last decade and have not previously been classified as separate product positions;
- the ability to dynamically evaluate product positions by comparing them over time, even over just the last few years;
- maximum detail[12], including intra-sectoral technological differentiation of goods.

The last criterion regarding the HS classification means that it is possible to single out six-figure product groups within four-figure groups based on technological level. In practice, this involves the use of an additional indicator as existing classifications follow the SITC format. Converting this into the HS format inevitably involves some loss of information. We propose using the excess 'price' of the product (the cost of 1kg) over the median for high-tech goods as this additional indicator.[13]

Converting the existing classifications to create a HS classification requires the use of conversion keys, which could include:

- the Eurostat classification (5-figure level SITC Rev. 4), based on R&D intensity data (Table 1);
- the Eurostat classification (3-figure level SITC Rev. 3) [Eurostat, 2015b] in Sanjaya Lall's refined version (3-figure level SITC Rev. *2* [*Lall*, 2000]).

Accordingly, 'cross-overs' are used for HS 2007 — SITC Rev. 3 and 4. The output list of products in the HS 2007 classification contains an indication as to the technological level and the value of additional indicators in both versions. Pooled data for the two classifications are used as a preliminary criterion to identify a high-tech product group.

All high-tech goods are distributed between two groups — medium (MHT) and very high-tech (HHT). The latter includes products whose 'price', i.e. unit cost, exceeds the median for high-tech goods in the five-figure classification used by Eurostat. Those that do not satisfy this criterion are assigned to the medium-high-tech group. Analysis has shown that 'price' cuts out goods with a low unit cost, which objectively reflects the higher average cost of high-tech goods compared with normal products.[14]

This method allows a list of 498 high-tech goods to be compiled[15], 317 of which are allocated to the medium-high-tech group and 181 to the very high-tech. These goods are aggregated into major groups to form a holistic impression of the structure of high-tech goods and to prepare an empirical basis to analyse the dependence of Russia's economy on technology imports. In total, this procedure created 12 major sectoral groups: 10 in mechanical engineering and 2 in the chemical industry (Table 2).

The majority of high-tech products (both in terms of number and volume of goods) fall under mechanical engineering and pharmaceuticals (Table 3).

The Global High-Tech Product Market

As of 2013, the size of the high-tech product market increased in absolute terms by almost a quarter compared with 2007 to roughly 2.9 trillion dollars[16] (by comparison, the global export market in 2013 had increased by 21% since 2007 to USD15.26 trillion). The share of the high-tech sector in the global market is roughly 18%. The very high-tech segment is valued at USD1.35 trillion. Over the period 2007–

[12] HS allows global trading to be classified into more than 5,000 product groups, compared with 1,000–2,500 (depending on the version and year) in the SITC classification.

[13] The literature offers numerous endorsements of the correlation between a product's price and its quality. A short review of studies on this topic is presented in [*Gnidchenko, Salnikov*, 2014].

[14] This assumption has been proven empirically: in 2013, the median price of a high-tech product in the Eurostat classification was USD 75 /kg, while a normal product was only USD 8 /kg. The gap in the average weighted price was higher still: 59 compared with USD 2 /kg.

[15] 'Arms and ammunition' (HS code 93) is excluded from the analysis.

[16] The size of the high-tech product market is estimated from exports, calculated from UN Comtrade data (most recent accessible data is for 2013), according to the developed classification.

Table 1. **High-tech goods in SITC version 4**

Sectoral groups	Goods
Aerospace industry	Airplanes and helicopters
	Spacecraft (including satellites) and launch vehicles
	Engines for airplanes, airframes and parts, propellers and rotors
	Direction compasses; navigation devices
Computer and office equipment	Office equipment connected to a computer or a network
	Computers
Electronics and telecommunications	Sound-recording and reproducing apparatus; video apparatus
	Telecommunications equipment
	Integrated circuit boards, printed circuit boards
	Panels and consoles for electrical apparatus
	Microwave tubes, lamps and other tubes
	Fiber-optic cables
	Semiconductor devices
	Optical and semi-conductor storage media
	Piezo-electric crystals
Pharmaceuticals	Antibiotics and derivatives; medicinal products containing antibiotics
	Hormones and derivatives; medicinal products containing hormones
	Glycosides, glands, immune sera (anti-sera), vaccines
Precision and medical apparatus	Electro-diagnostic and radiological apparatus
	Orthopedic appendages
	Drilling machinery
	Precision devices and instruments
	Optical devices and instruments
	Fiber-optics
	Contact lenses
	Photographic cameras, video apparatus
Electrical machinery and electronics	Electrical capacitors – fixed, variable or adjusting
	Electrical machinery with individual functions
	Sound or light signaling electrical equipment
Chemical industry	Selenium, tellurium, phosphorus, arsenic and boron
	Silicon
	Calcium, strontium and barium
	Radioactive substances
	Organic colorants, synthetic and pigmented varnishes
	Polyethylene terephthalate
	Insecticides and disinfectants
Machinery and equipment	Gas turbines and parts thereof
	Nuclear reactors and parts thereof, fuel rods
	Equipment, facilities and parts thereof to separate isotopes
	Machine tools for working with materials using laser beams
	Lathes with CNC
	Drilling machines with CNC
	Boring machines with CNC
	Milling machines with CNC
	Grinding machines with CNC
	Sharpening machines with CNC
Arms	Arms and ammunition

Source: [Eurostat, 2015a].

Table 2. Proposed classification based on major groups

Major group	OKVED code	HS 2007 code
Chemical Industry		
Pharmaceuticals	24.4	30
Chemistry (excluding pharmaceuticals)	DG, DH	28-29, 31-40
Mechanical Engineering		
Nuclear technologies	28.30.2	8401
Engines and turbines	DK	8406-8412
Machinery and equipment (excluding nuclear technologies, engines and turbines)	DK	8402-8405, 8413-8470, 8472, 847310, 847321, 847329, 847340, 847350, 8474-8487
Radio, TV, communications	DL	8517-8529, 8533-8534, 8540-8542
Other electrical equipment	DL	8501-8516, 8530-8532, 8535-8539, 8543-8548
Computer equipment	DL	8471, 847330
Optical equipment	DL	9001-9013
Medical equipment	DL	9018-9022
Precision instruments	DL	9014-9017, 9023, 91
Aircraft	DM	86-89

Source: compiled by the authors from UN Comtrade database.

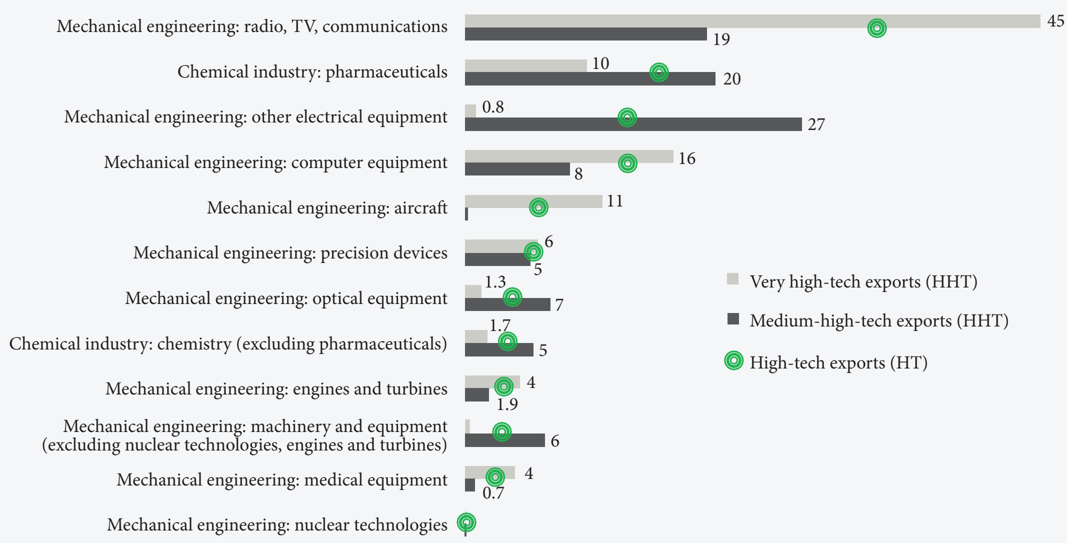
Table 3. Distribution of high-tech goods by major group

Technological level	Total	Chemical Industry		Mechanical Engineering										
		Pharmaceuticals	Chemistry (excluding pharmaceuticals)	Nuclear technologies	Engines and turbines	Machinery and equipment (excluding nuclear technologies, engines and turbines)	Radio, TV, communications	Other electrical equipment	Computer equipment	Optical equipment	Medical equipment	Precision instruments	Aircraft
Number of goods (6-figure HS 2007)													
HT	498	29	90	4	23	38	68	103	9	42	20	57	15
MHT	317	14	59	3	15	36	34	98	4	24	3	25	2
HHT	181	15	31	1	8	2	34	5	5	18	17	32	13
Global imports in 2013 *(billions of dollars)*													
HT	3477	469	125	5	132	91	1301	408	403	103	77	174	189
MHT	1530	305	87	4	27	88	328	392	130	80	10	77	2
HHT	1947	164	38	1	105	3	973	16	273	23	66	98	187
Global imports structure in 2013 *(%)*													
HT	100	13.5	3.6	0.1	3.8	2.6	37.4	11.7	11.6	3.0	2.2	5.0	5.4
MHT	100	19.9	5.7	0.3	1.8	5.8	21.4	25.6	8.5	5.2	0.7	5.0	0.1
HHT	100	8.4	2.0	0.03	5.4	0.2	50.0	0.8	14.0	1.2	3.4	5.0	9.6
Global net exports in 2013 *(billions of dollars)*													
HT	–187	5	–9	–0.4	–12	1	–203	17	–273	8	–1	5	–5
MHT	13	0.3	0.2	0.2	0.2	2	–31	18	-1	10	0.3	1	0.4
HHT	–200	5	–9	–1	–12	–1	–172	–0.3	–273	–2	–2	3	–6

Legend: HT — high-tech exports; MHT — medium-high-tech exports; HHT — very high-tech exports.

Source: authors' calculations from UN Comtrade database.

Fig. 1. **Sectoral structure of high-tech exports by major product group, average for 2012–2013 (%)**



Source: authors' calculations.

2013, the very high-tech product segment rose by more than 30%, slightly exceeding overall dynamics for the sector. Roughly 82% of the high-tech product market, according to average data for 2012–2013, is concentrated in mechanical engineering and the remainder in the chemical industry. Mechanical engineering still very much dominates in the very high-tech segment, with almost 90% market share.

The four leading major product groups (equipment for radio, TV and communications; pharmaceuticals; other electrical equipment and computer equipment) account for roughly three quarters of the global high-tech product market (Fig. 1). In the very high-tech product segment, the 'equipment for radio, TV and communications' major product group dominates[17], while for the high-tech product market as a whole 'other electrical equipment' dominates.[18]

The undisputed world leader of high-tech exports — China — remained firmly at the top of the rankings of major exporters over the period 2007–2013 both for the market as a whole and also, as expected, in the very high-tech segment. According to estimates for 2012–2013, China's share in global high-tech exports accounted for more than a quarter of the total volume, having increased by roughly 7 percentage points compared with average values for 2007–2008 (Table 4). The US and Germany are in second and third place respectively, with the gap between China and the US exceeding 15 percentage points in absolute terms. Germany's share has remained stable on average, at roughly 11% since 2007. Over these years, the US has lost 4 percentage points, with its share in the global market reduced from 15% to 11%. These negative dynamics are also characteristic of Japan's high-tech exports (minus 1.4 percentage points). Together with China, South Korea also consolidated its position in the global market, rising up the rankings from 7th to 4th place by keeping its market share at a stable level while other countries' shares declined. It should be noted that China's rapid expansion has led to greater concentration in the global high-tech market: the share of the 10 largest exporters in 2012–2013 increased by 1.5 percentage points compared with 2007–2008 to 81%.

China also occupies the top spot in world rankings for net exports of high-tech products (Table 5) with a share of roughly 37%, having increased by a considerable 9.7 percentage points over the last five years. Germany sits in second place with a share of 13% and South Korea third with 11%. Switzerland (9%), Ireland (6%), and Israel (2%) are also among the leaders in net exports of high-tech goods. Japan only occupies 17th place, while the US is a net importer of high-tech products. Together with China, Germany's share of global high-tech net exports increased over 2007–2013 by 2.2 percentage points, Switzerland by 1.7 percentage points, and Israel by 1.1 percentage points. The total contribution of these leading countries to global net exports increased from 81% in 2007–2008 to 96% in 2012–2013.

[17] The most important goods are telephones, processors and controllers, electronic integrated circuit boards and amplifiers, voice and other data transmission instruments, storage devices, TV cameras, transistors, and solid non-volatile data storage systems.

[18] The main goods in this group are static converters, boards, panels, consoles, switchboards for electrical equipment, batteries, lighting and warning devices, and fixed capacitors.

Table 4. **Largest high-tech exporters 2012–2013**

Exporting country	Ranking	Change in position	High-tech exports (*millions of dollars*)	Share of the global high-tech market (%)	Change in share of the global high-tech market (%)	Dominant high-tech product segment
China	1	—	761 906	27	⇈ (7.1)	HHT (57)
USA	2	—	317 573	11	↓ (–3.9)	HHT (57)
Germany	3	—	311 806	11	— (–0.4)	HHT (50)
South Korea	4	↑	167 827	6	— (0.5)	MHT (52)
Japan	5	↓	164 331	6	↓ (–1.4)	MHT (55)
Singapore	6	↓	160 744	6	— (0.1)	HHT (73)
France	7	↓	159 820	6	— (0)	HHT (67)
Netherlands	8	—	110 832	4	— (–0.4)	HHT (55)
Switzerland	9	↑	88 498	3	— (0.4)	MHT (53)
Belgium	10	↓	77 071	3	— (–0.4)	MHT (59)
Total for the largest exporters of high-tech products			2 320 410	81	↑ (1.5)	HHT (55)

Legend: HT — high-tech exports; MHT — medium-high-tech exports; HHT — very high-tech exports.

Source: authors' calculations from UN Comtrade database.

China dominates in terms of its share of global net exports of major product groups such as computer equipment (88%) and machinery and equipment excluding nuclear technologies, engines and turbines (59%). Germany has a strong position in exports of medical equipment (35%), precision devices (35%), aircraft (32%), pharmaceuticals (21%), and engines and turbines (18%). South Korea is the leader in optics (59%) and radio, TV and communications equipment (42%). Ireland occupies other positions in high-tech pharmaceutical output (18%) and medical equipment (12%).

In certain sectoral groups, especially in the high-tech segment, the distribution of leading countries is even more clear-cut: 87% of computer equipment and 62% of machinery and equipment (excluding nuclear technology, engines and turbines) are exported by China, 41% of optical and 37% of medical equipment by Germany, 61% of radio, TV and communications equipment by South Korea, 42% of aircraft and 30% of engines and turbines by France, and 71% of other electrical equipment by Japan. Thus, the growth in China's share of net global exports over the period 2007–2013 was in fact 21.6 percentage points.

Method of Identifying a Country's Dependence on Technology Imports

The level of dependence of Russia's economy on high-tech imports can be estimated using the competitiveness index and the share of imports from countries that have imposed sanctions on Russia.

Table 5. **Major net exporters of high-tech products in 2012–2013**

Exporting country	Ranking	Change in position	Net exports of high-tech products (millions of dollars)	Share of global net exports of high-tech products (%)	Change in share of global net exports of high-tech products
China	1	—	177 619	37	⇈ (9.7)
Germany	2	↑	74 137	15	↑ (2.2)
South Korea	3	↓	70 391	15	— (1)
Switzerland	4	↑	41 055	9	↑ (1.7)
Singapore	5	—	36 806	8	— (0.3)
Ireland	6	↑	27 990	6	— (-0.6)
France	7	↑	14 053	3	— (-0.2)
Israel	8	↑	8 744	2	↑ (1.1)
Belgium	9	↑	6 323	1	— (0.6)
Netherlands	10	↑	6 252	1	— (-0.1)
Total for the largest net exporters of high-tech products			463 371	96	⇈ (15.7)

Source: authors' calculations from UN Comtrade database.

Competitiveness index

One of the most widely-known approaches to estimating a country's competitiveness in global goods markets is the Balassa index [*Balassa*, 1965]:

$$BI_{i,c,t} = \left(\frac{X_{i,c,t}}{\sum_i X_{i,c,t}} \right) \Bigg/ \left(\frac{\sum_c X_{i,c,t}}{\sum_{ic}\sum X_{i,c,t}} \right), \quad (1)$$

where $X_{i,c,t}$ is exports of product *i* by country *c* in year *t*.

If this index is higher than one, this signals a country's comparative advantage in the global trade for a particular product. However, the index does not allow for a direct comparison of the competitiveness of individual economies due to at least three key shortcomings. First, sensitivity to the number of exported goods: the importance of small countries with a small product nomenclature will be over-stated. Second, structural distortions: a very high share in exports of certain goods (for example, oil and gas in Russia's case) leads to an automatic reduction in other positions. Third, the index does not take into account import trade flows, linked to defining a country's position solely on the basis of data on goods exports.

These problems can be partly overcome by using another frequently used indicator — the trade imbalance coefficient [UNIDO, 1982]:

$$RNX_{i,c,t} = \frac{X_{i,c,t} - M_{i,c,t}}{X_{i,c,t} + M_{i,c,t}}, \quad (2)$$

where $M_{i,c,t}$ is imports of product *i* by country *c* in year *t*.

The value fluctuates between –1 and 1, reflecting the trade balance of a country for the particular product for which the calculation is being carried out. Such an approach rules out structural distortions and the dependence of the coefficient on the number of exported goods. Its shortfall is that it does not take trading volume into account. Thus, it can give the value +1 even if exports of a particular product are near zero, but imports are lacking.

For an adequate assessment of a country's competitiveness in global goods markets, we propose the following *competitiveness index:*[19]

$$RNX^{E}_{i,c,t} = \left(\underbrace{\frac{X_{i,c,t} - M_{i,c,t}}{X_{i,c,t} + M_{i,c,t}}}_{RNX_{i,c,t}} \right) \cdot \left(\frac{X_{i,c,t} + M_{i,c,t}}{GDP_{c,t}} \Bigg/ \frac{\sum_c X_{i,c,t} + \sum_c M_{i,c,t}}{\sum_c GDP_{c,t}} \right), \quad (3)$$

where $GDP_{c,t}$ is the GDP of country *c* in year *t* at current prices.

The index is an imbalance coefficient, adjusted to fit the intensity of trading relative to GDP, and gives values from $-\infty$ to $+\infty$ (for Russia, the major product groups range from –0.5 to 4.3). It combines the advantages of the trade imbalance coefficient and the Balassa index. The value corresponds to a product's foreign trade balance, reflecting average global trading intensity with minimal influence from structural distortions.

Additionally, the following points need to be taken into account when analyzing the results:

- the value of the index for developed countries, as a negative value where there are global centers of specialization does not necessarily point to a country's weak competitiveness (for example, the primary exporter of computer equipment is China, so even developed countries have negative index values for this product group);
- the trade imbalance coefficient to cleanse the data of any influence from trading intensity (thus, if a country is involved in some minor way in the value added chain, the competitiveness index value may be understated).

Interrelationships between Russian and global import structures

We will also analyze the share of imports of countries that have imposed sanctions against Russia: the US, Canada, Australia, Norway, EU countries, Switzerland, and Japan. Since these countries coordinate on foreign economic policy, it is sensible to view them as a single trading partner. In the event of a deterioration in relations, dependence on these countries could seriously impede Russian businesses' access to certain technologies. The proposed indicator actually allows for an approximate estimate of the level of dependence on imports and the associated threat to a country's technological security. The value of the indicator both in absolute terms and in relation to global average levels is important to note. The

[19] An in-depth justification for this index is given in [*Gnidchenko, Salnikov*, 2015].

global share of imports of countries that introduced sanctions against Russia needs to be calculated and compared with the detailed structure of Russian imports (6 HS 2007 classifications), which will allow the effect of the sanctions to be offset.

An Assessment of Russia's Economic Dependence on High-Tech Imports

For the majority of major product groups, Russia's dependence on high-tech imports is estimated to be high. In the chemical and mechanical engineering industries, 2007–2013 exhibited extremely low figures compared with developed countries (Table 6). The share of imports from countries that have imposed sanctions on Russia exceeds 60% in mechanical engineering, which is significantly higher than the average in other global economies. A similar picture is painted by the segment for very high-tech goods (Table 7), with the differentiation of product groups both in absolute terms of their dependence on imports and in terms of dynamics pointing to three categories of countries: leaders, middle-performers, and outsiders.

Leaders

Russia occupies leading positions in foreign trading in goods linked to nuclear technologies, engines and turbines, and exports of these goods far exceed imports. Russia has virtually no dependence on imports; the country is able to independently satisfy its own needs. Russia holds strong positions, even compared with developed countries, and has some of the strongest competitive advantages in the field of fuel elements (TN VED 840130), exports of which amount to almost USD1.31 billion per year, with aggregate turnover in the sector at USD1.34 billion per year. Small import volumes, which fail to surpass exports, are only observed for nuclear reactor parts (TN VED 840140).

Russia's positions overall in the 'engines and turbines' group are slightly positive, however the competitiveness index fell somewhat over the period 2007–2013. For very high-tech goods in this group, the situation is slightly better, but the overall downward trend in competitiveness remains. From the perspective of Russia's independence from countries that have imposed sanctions, the situation appears moderately strained: the share of imports from these countries accounts for 58% compared with 81% on average globally. The greatest dependence — over 90% — is seen in segments such as turbojets and turboprops (TN VED 841199) and reaction engines, excluding turbojets (TN VED 841210).[20] Russia's

Table 6. **Russia's economic dependence on high-tech imports***

Major product group	Competitiveness index		Russian Federation trade imbalance coefficient	Share of imports from countries that have imposed sanctions against Russia (%)*	
	Russia	US, EU, Japan		Russia	World**
Average data for 2012–2013 and (in brackets) average for 2007–2008					
Chemical Industry	**-0.43 (-0.38)**	0.03 (0.02)	-0.85 (-0.84)	**85 (82)**	85 (90)
Pharmaceuticals	**-0.49 (-0.41)**	0.06 (0.05)	-0.91 (-0.92)	**91 (93)**	90 (94)
Chemistry (excluding pharmaceuticals)	**-0.22 (-0.3)**	-0.08 (-0.08)	-0.54 (-0.6)	**44 (40)**	63 (74)
Mechanical Engineering	**-0.2 (-0.22)**	-0.05 (-0.02)	-0.6 (-0.65)	**62 (73)**	45 (56)
Nuclear technologies	**4.39 (4.82)**	0.05 (0.25)	0.98 (0.99)	**47 (100)**	72 (75)
Engines and turbines	**0.01 (0.09)**	0.06 (0.19)	0.01 (0.19)	**58 (59)**	81 (89)
Machinery and equipment (excluding nuclear technologies, engines and turbines)	**-0.49 (-0.47)**	-0.05 (-0.07)	-0.89 (-0.92)	**76 (81)**	54 (65)
Radio, TV, communications	**-0.15 (-0.23)**	-0.11 (-0.08)	-0.73 (-0.85)	**49 (64)**	31 (44)
Other electrical equipment	**-0.28 (-0.31)**	0.05 (0.06)	-0.67 (-0.68)	**64 (67)**	54 (63)
Computer equipment	**-0.23 (-0.22)**	-0.24 (-0.25)	-0.9 (-0.93)	**49 (81)**	30 (41)
Optical equipment	**-0.12 (-0.12)**	0.1 (0.06)	-0.64 (-0.63)	**41 (78)**	29 (34)
Medical equipment	**-0.47 (-0.46)**	0.09 (0.1)	-0.94 (-0.92)	**92 (95)**	86 (90)
Precision devices	**-0.22 (-0.22)**	0.22 (0.21)	-0.51 (-0.5)	**84 (89)**	76 (85)
Aircraft	**-0.23 (-0.13)**	0.14 (0.38)	-0.47 (-0.36)	**88 (93)**	84 (90)

* For Russia, imports are estimated from mirror statistics on the exports of other countries, as domestic data is significantly distorted by surges in the country structure of imports for certain goods. A particularly large effect was observed in the 'precision devices' major product group, due to overestimates of imports from Belarus in Russian data. Significant discrepancies can also be detected between Russian and Chinese data.

** US, Canada, Australia, Norway, EU countries, Japan, Switzerland.

*** Weighted structure of Russian imports in the six-figure level of the HS 2007 classification.

Source: CMASF calculations from UN Comtrade data.

[20] Here and subsequently in the text, goods playing a minor role in Russia's foreign trade turnover with a total share of less than 5% will not be mentioned.

Table 7. **The Russian economy's dependence on very high-tech imports***

Major product group	Competitiveness index		Russian Federation trade imbalance coefficient	Share of imports from countries that have imposed sanctions against Russia (%)*	
	Russia	US, EU, Japan		Russia	World**
Average data for 2012–2013 and (in brackets) average for 2007–2008					
Chemical Industry	**-0.33 (-0.35)**	0.01 (0.00)	-0.83 (-0.85)	**82 (77)**	93 (96)
Pharmaceuticals	**-0.31 (-0.32)**	0.06 (0.08)	-0.89 (-0.93)	**97 (98)**	95 (96)
Chemistry (excluding pharmaceuticals)	**-0.44 (-0.45)**	-0.22 (-0.25)	-0.67 (-0.53)	**37 (30)**	80 (94)
Mechanical Engineering	**-0.18 (-0.2)**	-0.07 (0.01)	-0.63 (-0.66)	**61 (77)**	44 (58)
Nuclear technologies	**0.04 (1.33)**	0.74 (0.34)	0.07 (0.69)	**46 (100)**	89 (91)
Engines and turbines	**0.06 (0.12)**	0.03 (0.21)	0.1 (0.31)	**55 (56)**	83 (90)
Machinery and equipment (excluding nuclear technologies, engines and turbines)	**-0.09 (-0.09)**	-0.29 (-0.21)	-0.25 (-0.28)	**85 (79)**	43 (62)
Radio, TV, communications	**-0.14 (-0.23)**	-0.11 (-0.04)	-0.79 (-0.86)	**45 (68)**	29 (44)
Other electrical equipment	**0.04 (-0.02)**	0.19 (0.19)	0.15 (-0.14)	**78 (75)**	45 (54)
Computer equipment	**-0.25 (-0.22)**	-0.31 (-0.31)	-0.92 (-0.94)	**38 (80)**	27 (41)
Optical equipment	**-0.25 (-0.22)**	0.18 (0.16)	-0.55 (-0.62)	**70 (83)**	68 (63)
Medical equipment	**-0.5 (-0.48)**	0.09 (0.11)	-0.95 (-0.93)	**91 (95)**	86 (90)
Precision devices	**-0.26 (-0.28)**	0.23 (0.23)	-0.65 (-0.63)	**90 (94)**	77 (87)
Aircraft	**-0.24 (-0.14)**	0.14 (0.38)	-0.5 (-0.36)	**88 (93)**	84 (90)

* US, Canada, Australia, Norway, EU countries, Japan, Switzerland.

** Weighted structure of Russian imports in the six-figure level of the HS 2007 classification.

Source: CMASF calculations from UN Comtrade data (Russian imports from mirror statistics).

key partners in this sector are Ukraine (36% of imports in 2012–2013), Germany (16%), Italy and France (7% each), the UK (5%), and the US (4%).

Analysis of the specific nature of the specialization in certain goods means that Russia can be categorized as a niche producer. The competitiveness index of developed countries, which is positive for a wide range of goods, is only significantly positive in the case of Russia for turbojets with thrust over 25 kN (TN VED 841112), reaction engines, excluding turbojets (TN VED 841210), and gas turbines with a maximum power of 5,000 kW (TN VED 841181). For water turbines and water wheels (TN VED 841090), Russia lost its leadership over the course of the analyzed time period, while for turboprops with power over 1,100 kW (TN VED 841122) and without, its critical dependence on imports has significantly intensified.

Middle-performers

7 major product groups can be classed as middle-performers.

For the *'chemistry (excluding pharmaceuticals)'* group, Russia's competitiveness can be described as slightly negative. In the very high-tech segment, the situation is somewhat worse than for high-tech goods on average. Russia's competitiveness in this major group is on the whole worse than that of developed economies. With the significant overall reduction in Russia's dependence on imports, especially from the countries that have imposed sanctions, this figure increased slightly over the period 2007–2013, which can be explained by the change in the product structure of imports: a fall in the share of polyethylene terephthalate (TN VED 390760) and an increase in the share of natural uranium (TN VED 284410).

The dependence of developed countries is determined by the position of uranium in the imports structure, whereas Russia, in addition to natural uranium, imports polyethylene terephthalate, herbicides (TN VED 380893), fungicides (TN VED 380892), and insecticides (TN VED 380891). Over the period 2007–2013, Russia consolidated its competitiveness for three main goods: polyethylene terephthalate (TN VED 390760), herbicides (TN VED 380893), and radioactive elements and isotopes (TN VED 284440). The largest decrease was seen in polypeptide hormones (TN VED 293719) and alkali and alkaline earth metals (TN VED 280512).

For the *'optical equipment'* group, Russia still maintains moderate and stable but weak positions. From 2007 onwards, there was a sharp decline in Russia's dependence on imports from countries imposing sanctions — from 78% to 41%, however, this was largely due to growth in China's share of imports from 21% to 88% for one of the largest product positions — liquid crystal instruments and devices (TN VED 901380). Dependence on imports of other goods from the 'sanctioning' countries, taking into account import volumes, did not reduce that dramatically on average — from 81% to 68%.

Among its specialist areas are lasers (TN VED 901320), for which its competitiveness index moved from the negative into the positive over the period 2007–2013, lenses, prisms and mirrors (TN VED 900190), and monoculars and telescopes (TN VED 900580). A slight increase was recorded for all types of microscopes (TN VED 901210, 901180), excluding stereoscopic (TN 901110), which demonstrated acute negative trends. Of the major product groups, Russia's competitiveness worsened for telescopic sights (TN VED 901310), binoculars (TN VED 900510), and projection screens (TN VED 901060).

Russia's competitiveness in *precision devices* can be described as moderately weak and relatively stable over the period 2007–2013 amid consistently positive values among developed countries. Russia's dependence on imports from countries that have imposed sanctions is overall high for this sector (84%), especially for devices used in physical or chemical analysis (TN VED 902780), flow and liquid level control (TN VED 902610), liquid and gas characteristic control (TN VED 902680), and devices based on optical radiation (TN VED 902750). However, over the period 2007–2013, it reduced slightly due to growth in the shares of South Korea, China, and several other countries in imports of a wide range of highly important goods and a reduction in Germany's share. The greatest reduction in the share of imports from 'sanctioning' countries was recorded in product groups such as automatic regulation and control devices (TN VED 903289), topographical, meteorological and geophysical devices (TN VED 901580), and parts for such devices (TN VED 901590).

For the majority of product groups, Russia's competitiveness index is in the negative. The exceptions are only aerospace navigation devices (TN VED 901420, 901480), demonstration instruments and models (TN VED 902300), and parts for compasses and navigation devices (TN VED 901490).[21] For the majority of other goods, Russia finds itself highly dependent on imports. The worst situation is encountered with devices to detect and measure ionizing radiation (TN VED 903010): while in 2007–2008 the Russia's competitiveness index was positive, in 2012–2013 it fell to –0.4. The competitiveness index is no higher than –0.4 for several other product groups too, including topographical, meteorological and geophysical devices and parts, flow and liquid level control, devices based on optical radiation, and devices for liquid and gas characteristic control.

Over the period 2007–2013, Russia's positions in the *aircraft* sector somewhat deteriorated, unlike developed countries, whose high competitiveness still shows negative trends, due to the gradual reduction in their share of the global market. The majority of goods in this group are very high-tech. Russia's dependence on imports of aircraft from countries that have imposed sanctions is extremely high (88%), one of the most notable figures among the major product groups.[22] The main countries supplying high-tech aircraft to Russia are France and the US, while developing countries are very poorly represented due to the specifics of the market. The key imported goods in this sector are airplanes with a mass over 15 t (TN VED 880240), spacecraft (TN VED 880260), and aircraft parts (TN VED 880330, 880390). For helicopters with a mass over 2 t (TN VED 880212) and for aircraft parts (TN VED 880390), the export-import balance has suffered a significant downturn, making a considerable contribution to the reduction in the sector's overall competitiveness. Over the period 2007–2013, this figure increased slightly only for airplanes with a mass between 2 and 15 t (TN VED 880230) and airframes (TN VED 880320). For other goods, the country's positions remain stable.

In the '*other electrical equipment*' group, Russia is maintaining stable but negative positions, while in the very high-tech goods segment,[23] the competitiveness index over the period 2007–2013 moved into the positive. Russia's dependence on countries imposing sanctions is relatively high due to the high proportion of German imports — 20% compared with 17% from China, with the gap gradually declining.[24] Russia mostly imports power generators (TN VED 850239, 850220, 850212, 850211), boards, panels, and consoles (TN VED 853710), and lighting and visual warning devices (TN VED 851220) from Germany and static converters (TN VED 850440) and AC motors (TN VED 850153, 850140) from China. For almost all other goods, excluding lead batteries (TN VED 850710), Russia's share of imports from countries imposing sanctions fell over the period 2007–2013.

Specializing in signal generators and apparatus with specific functions (TN VED 854320) and equipment for rail and tram lines (TN VED 853010) does not offer Russia any significant advantages as these product groups are traded in comparatively small volumes. As for the rest, the highest level of dependence on imports is recorded in electrodes (TN VED 854519), machinery for metal welding (TN VED 851531) and electric generator sets (TN VED 850239, 850220). A significant improvement in Russia's position over the period 2007–2013 is linked to these areas. A downturn in competitiveness has occurred in the major product groups of AC motors (TN VED 850152, 850153) and electrodes used in ovens (TN VED 854511).

[21] It should be noted that in 2007–2013, Russia's competitiveness in these areas intensified.

[22] A key contribution to this figure came from long-range aircraft, for which Russia's dependence on imports from developed countries is as high as 98%.

[23] The main products in the segment are electrodes used in ovens (TN VED 854511), polyphase AC motors with a power rating over 75 kW (TN VED 850153), lead batteries (TN VED 850720), luminescent lamps with an incandescent cathode (TN VED 853931), and liquid-filled transformers (TN VED 850421).

[24] Third place is occupied by Ukraine with 8%.

As for the *'computer equipment'* group, Russia's position has remained firmly negative. Despite a slightly more optimistic competitiveness index value, the trade imbalance coefficient points to imports far exceeding exports, which reflects the low level of trading intensity as a result of the country's poor integration in global added value chains in this sphere. Developed economies are still characterized by a negative competitiveness index as China remains the undisputed leader of global exports. Over the period 2007–2013, its share rose from 36% to 43% and from 12% to 42% of Russia's imports — mostly due to major products such as portable computer equipment (TN VED 847130) accounting for roughly 44% of imports in this product group. Interestingly, by 2012–2013, Russia's dependence on imports from countries that have imposed sanctions dropped to virtually zero in this product area, while other goods remained almost unchanged, fluctuating between 65–85%. Therefore, while for the group overall Russia's dependence on imports from 'sanctioning' countries over the period 2007–2013 declined from 81% to 49%, if we exclude portable computer equipment from the calculations, the shift is far more modest — from 86% to only 80%.

We note that for this group Russia's product specialism structure is virtually the same as that of the US, EU, and Japan. This means that there is a strong specialist center among developing countries — primarily, China which exports goods to developed countries, among others. Thus, Russia's dependence on computer imports cannot be deemed excessive, but rather in line with global trends.

For the 'radio, TV and communications' product group, the assessment of the previous group is generally fitting: Russia's competitiveness index is firmly in the negative with a slight positive trend. This does not mean that the situation is critical due to the significant dependence on imports of this category of goods in developed countries too. Russia's share of imports from countries that have imposed sanctions is relatively small in this sector, while dynamics are on the whole positive. As for the 'computer equipment' group, the main contribution to global exports and Russia's imports comes from China. On a detailed level, over the period 2007–2013 Russia reduced its dependence on countries that have imposed sanctions for an extremely wide range of goods: telephones for mobile communications networks (TN VED 851712),[25] voice and image processing systems (TN VED 851762), television receivers (TN VED 852872), processors and controllers (TN VED 854231), and many more (due to a global trend of China's and other South East Asian countries' growing competitiveness in this area).

The situation with certain goods, however, was far less homogeneous than that of computer equipment. Despite the fact that developed countries are dependent on imports of the majority of product groups, they have their own areas of specialism, exporting radar equipment (TN VED 852610), processors and controllers (TN VED 854231), and storage devices (TN VED 854232). Russia's competitiveness, even compared with developed countries, is only strong in radar equipment. The clearest dependence is seen in imports of voice and image transmission equipment (TN VED 851761), radio electronics (TN VED 852990), and radio navigation devices (TN VED 852691).

Outsiders

3 major product groups can be classed as outsiders.

Russia's dependence on imports of *pharmaceuticals* is extremely high, while developed countries have fairly strong positions in this market. A similar situation can be seen in the very high-tech pharmaceuticals segment. In this area, Russia has been relatively highly and consistently dependent on imports from sanctions-imposing countries: their share of imports is over 90%, which is generally in line with the global average. Russia's main partners in this product group are Germany and Belgium, with 19% and 13% of imports respectively. The strongest dependence on imports in major product groups can be observed in anti-sera (TN VED 300210), drugs containing alkaloids (TN VED 300440), corticosteroid hormones (TN VED 300432), and insulin (TN VED 300431).

The level of concentration on the pharmaceutical market is extremely high – over 60% of Russian and global imports are in the product group 'other medicinal products' (TN VED 300490), which severely restricts the possibility of an in-depth analysis of the imports structure. Nevertheless, we can deduce that Russia has a direct dependence on imports (in the majority of cases, with negative trends) given the very strong competitiveness of the US, EU, and Japan across all product lines. Particularly pronounced is Russia's dependence on drugs containing vitamins (TN VED 300450) and alkaloids.

For the product group *'machinery and equipment (excluding nuclear technologies, engines and turbines)'*, Russia's competitiveness index and trade imbalance coefficient are in a very poor position — roughly –0.5 and –0.9 respectively. The positions of developed countries are generally balanced and cannot unequivocally be qualified as weak or strong. Russia's economic dependence on imports of machinery and equipment in this group from countries that have imposed sanctions remains moderate overall

[25] For telephones for mobile communications networks, over the period 2007–2013 there was an increase in the concentration of imports due to China taking up a dominant position in terms of export volumes to Russia. At the start of this period, countries such as Hungary, South Korea, and Finland competed directly with China. We note also that Russia's imports in this group fell from more than USD 4 to 2.4 billion. This may be due to the growing share of imports of smartphones and tablets which can be classified as portable computer equipment (TN VED 847130).

compared with other major product groups, although it does exceed the average global level (primarily, from Germany, Italy, and Finland). The highest dependence on imports from developed countries is seen in machine tools with computer numerical control (CNC) (TN VED 845811, 846221, 845961, 846241, 845931, 846021). Russia's geographical structure of imports over the period 2007–2013 has remained virtually unchanged, although there has been a slight reduction in its dependence on imports from 'sanctioning' countries, primarily on account of coin sorting and counting machinery (TN VED 847290), printers and copiers (TN VED 844332), pneumatically-operated hand tools (TN VED 846729), machinery performing two or more functions (TN VED 844331), and metal-cutting lathes (TN VED 845811).

Russia's competitiveness on the global market for certain goods is low. Developed countries are fairly often dependent on imports in some respects, but have an area of specialization — for machine tools with computer numerical control, parts for metal processing tools (TN VED 846693, 846694), metal processing tools using radiation (TN VED 845610), etc. Russia has the worst level of competitiveness in bending machines with computer numerical control (TN VED 846221), mechanical shears (TN VED 846231), and lathes with computer numerical control (TN VED 845811, 845891).

While *medical equipment* is one of the areas of specialization of developed countries, in Russia demand for goods in this group is largely satisfied through imports. The country's position on the whole looks stable over the period under examination: from 2007, both the competitiveness index and the trade imbalance coefficient remain extremely low, as before. Russia is critically dependent on imports of medical equipment from countries that have imposed sanctions, primarily from Germany, the Netherlands, France, and the US, which account collectively for 92% of imports into the Russian Federation — the highest figure among all the major product groups. Among the products with the highest level of dependence on imports from developed countries are CT and MRI units (TN 902212, 901813), artificial joints (TN VED 902131), and X-ray equipment (TN VED 902214). We note that over the period 2007–2013, Russia's dependence on imports from 'sanctioning' countries declined for the majority of goods. The exceptions were X-ray tubes (TN VED 902230) and pacemakers (TN VED 902150).

Russia's direct dependence on imports of medical equipment, areas where developed countries generally maintain strong positions, is shown across a wide range of products. The lowest competitiveness index was in CT units (TN VED 902212), dental drills (TN VED 901841), ultrasound scanning equipment (TN VED 901812), and equipment using alpha-, beta- and gamma-radiation (TN VED 902221).

Conclusions and recommendations

Our study has shown that Russia is a strongly niche producer of high-tech products with weak competitiveness in the majority of goods and a high level of dependence on imports from sanctions-imposing countries. In the short-term, a re-orientation towards imports from other states with different global market positions could help to overcome this situation. Israel and South East Asian countries such as China, South Korea, Hong Kong, and Singapore represent potential trading partners for Russia: collaborating with these countries could significantly reduce Russia's dependence on 'sanctioning' countries for the overwhelming majority of major high-tech product groups (Table 8).

Table 8. **Potential trading partners for Russia**

Major product group	Potential trading partners (leading countries in global exports of high-tech products)
Chemical Industry	
Pharmaceuticals	India, Singapore, Israel
Chemistry (excluding pharmaceuticals)	China, Kazakhstan, India, South Korea, Thailand, Israel, Indonesia
Mechanical Engineering	
Nuclear technologies	South Korea, China
Engines and turbines	China, Singapore, Hong Kong
Machinery and equipment (excluding nuclear technologies, engines and turbines)	China, Indonesia, South Korea, Thailand, Hong Kong, Malaysia, Singapore
Radio, TV, communications	China, South Korea, Hong Kong, Singapore, Vietnam
Other electrical equipment	China, South Korea, Hong Kong, Malaysia, Thailand, Singapore
Computer equipment	China, Hong Kong, Singapore, Thailand, South Korea
Optical equipment	China, South Korea, Hong Kong, Singapore, Thailand
Medical equipment	China, South Korea, Singapore, Israel
Precision devices	China, Singapore, South Korea
Aircraft	Brazil

Source: CMASF calculations from UN Comtrade data.

In the long-term, Russian production requires further development, especially for those goods with a very high share of imports from countries that have imposed sanctions:

- in the pharmaceutical industry this primarily relates to anti-sera and drugs containing alkaloids, hormones and insulin;
- in mechanical engineering, civilian aircraft, medical equipment and precision devices (within these groups dependence can be seen across a wide range of goods);
- in other mechanical engineering sectors, where the overall dependence on imports is still moderate, this includes product groups such as machine tools with computer numerical control, generator units, and microscopes.

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References

Balassa B. (1965) Trade Liberalization and Revealed Comparative Advantage. *Manchester School of Economic and Social Studies*, vol. 33, no 2, pp. 99–123.
Bas M., Berthou A. (2012) The Decision to Import Capital Goods in India: Firms' Financial Factors Matter. *World Bank Economic Review*, vol. 26, no 3, pp. 486–513.
Bas M., Strauss-Kahn V. (2014) Does Importing More Inputs Raise Exports? Firm-Level Evidence from France. *Review of World Economics*, vol. 150, no 2, pp. 241–275.
Caselli F., Wilson D. (2004) Importing Technology // Journal of Monetary Economics, vol. 51, no 1, pp. 1–32.
Coe D., Helpman E. (1995) International R&D Spillovers. *European Economic Review*, no 39, pp. 859–887.
Colantone I., Crino R. (2014) New Imported Inputs, New Domestic Products. *Journal of International Economics*, vol. 92, no 1, pp. 147–165.
Eurostat (2015a) *Eurostat indicators on High-tech industry and Knowledge-intensive services. Annex 5 — High-tech aggregation by SITC Rev. 4*, Luxembourg: Eurostat. Available at: http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf, accessed 15.09.2015.
Eurostat (2015b) LALL's technological classification of export. Luxembourg: Eurostat. Available at: http://ec.europa.eu/eurostat/ramon/documents/lall/LALL_SITC_Rev_3.zip, accessed 15.09.2015.
Feng L., Li Z., Swenson D. (2012) *The Connection between Imported Intermediate Inputs and Exports: Evidence from Chinese Firms* (NBER Working Paper no 18260), Cambridge, MA: National Bureau of Economic Research.
Gnidchenko A., Salnikov V. (2014) Tsenovaya konkurentosposobnost' rossiiskoi vneshnei torgovli [Russian Foreign Trade Price Competitiveness]. *Voprosy Ekonomiki*, no 1, pp. 108–129 (in Russian).
Gnidchenko A., Salnikov V. (2015) *Net Comparative Advantage Index: Overcoming the Drawbacks of the Existing Indices* (NRU HSE Basic Research Program Working Paper WP BRP 119/EC/2015), Moscow: National Research University Higher School of Economics.
Griliches Z. (1973) Research Expenditures and Growth Accounting // Science and Technology in Economic Growth / Ed. B. Williams. New York: John Wiley & Sons, Halsted Press, pp. 59–95.
Griliches Z., Lichtenberg F. (1984) Interindustry Technology Flows and Productivity Growth: A Reexamination. *Review of Economics and Statistics*, vol. 66, no 2, pp. 324–329.
Hatzichronoglou T. (1997) *Revision of the High-Technology Sector and Product Classification* (OECD Science, Technology and Industry Working Paper no 1997/02), Paris: OECD.
Keller W. (2000) Do Trade Patterns and Technology Flows Affect Productivity Growth? *World Bank Economic Review*, vol. 14, no 1, pp. 17–47.
Krammer S. (2014) Assessing the Relative Importance of Multiple Channels for Embodied and Disembodied Technological Spillovers. *Technological Forecasting and Social Change*, vol. 81, pp. 272–286.
Lall S. (2000) *The Technological Structure and Performance of Developing Country Manufactured Exports, 1985–1998* (University of Oxford QEH Working Paper no 44), Oxford: University of Oxford.
Lichtenberg F., van Pottelsberghe de la Potterie B. (1998) International R&D Spillovers: A Re-Examination (NBER Working Paper no 5668), Cambridge, MA: National Bureau of Economic Research.
OECD (2011) *ISIC rev. 3. Technology intensity definition. Classification of manufacturing industries into categories based on R&D intensities*, Paris: OECD. Available at: http://www.oecd.org/sti/ind/48350231.pdf, accessed 12.09.2015.
Papaconstantinou G., Sakurai N., Wyckoff A. (1996) *Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries* (OECD Science, Technology and Industry Working Paper no 1996/01), Paris: OECD.
Scherer F. (1982) Inter-Industry Technology Flows and Productivity Growth. *Review of Economics and Statistics*, vol. 64, no 4, pp. 627–634.
Stone S., Shepherd B. (2011) *Dynamic Gains from Trade: The Role of Intermediate Inputs and Equipment Inputs* (OECD Trade Policy Paper no 110), Paris: OECD.
Terleckyj N. (1974) *Effects of R&D on the Productivity Growth of Industries: An Exploratory Study*, Washington, D.C.: National Planning Association.
Terleckyj N. (1980) Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries. *New Developments in Productivity Measurement* (eds. J. Kendrick, B. Vaccara), Chicago: University of Chicago Press, pp. 357–386.
Trilateral Patent Offices (2007) Trilateral Statistical Report. 2007 Edition. Munich: European Patent Office, Japan Patent Office, United States Patent and Trademark Office. Available at: http://www.trilateral.net/statistics/tsr/2007/TSR.pdf, accessed 21.09.2015.
UNIDO (1982) *Changing Patterns of Trade in World Industry: An Empirical Study on Revealed Comparative Advantage*, New York: United Nations.
Wolff E., Nadiri I. (1993) Spillover Effects, Linkage Structure, and Research and Development. *Structural Change and Economic Dynamics*, vol. 4, no 2, pp. 315–331.
Xu B., Wang J. (1999) Capital Goods Trade and R&D Spillovers in the OECD. *Canadian Journal of Economics*, vol. 32, pp. 1258–1274.
Zhu L., Jeon B. (2007) International R&D Spillovers: Trade, FDI, and Information Technology as Spillover Channels. *Review of International Economics*, vol. 15, no 5, pp. 955–976.