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THE STRUCTURE OF THE WORLD ADVANCED MANUFACTURING: ESTIMATION USING MULTI-REGIONAL INPUT-OUTPUT TABLES EORA, WIOD AND OECD-ICIO

A. Bykau
doctor of economic sciences, professor, vice-rector for research at BSEU

U. Parkhimenka
ph. d., associate professor, head of the department of economics at BSUIR

V. Vernyakhovskaya
master of economics, deputy dean of the faculty of engineering and economics at BSUIR

Belarus State Economic University, Republic of Belarus
Belarusian State University of Informatics and Radioelectronics, Republic of Belarus
E-mail: aliaksei.bykau@yandex.ru, parkhimenko@bsuir.by, verniahovskaya@bsuir.by

A. Bykau

Graduated from BSEU. Doctor of economic sciences, full professor. Works as a vice-rector for research at BSEU. Scientific research area: economic growth and development, input-output economics, global value chains, crisis management. Has more than 150 publications, including 7 monographs.

U. Parkhimenka

Graduated from BSUIR. PhD in economics, associate professor. Works as a head of economics department at BSUIR. Research interests include input-output analysis of economic processes at national, regional and global levels.

V. Vernyakhovskaya

Graduated from BSUIR. Master of economics. Works as a deputy dean of the faculty of engineering and economics at BSUIR. Research areas: technology transfer, innovative activity, information technologies in marketing.

Abstract. The future of the world economy is usually associated with the development of an innovative sector, where human capital is the main production factor. Despite the general trend of growth in the service sector, a strong manufacturing industry remains a prerequisite for the innovative development of the economy, especially the most innovative part of manufacturing including the production of electronics, robots, machinery and equipment, and vehicles. The degradation of industrial capacity deprives a national economy of growth opportunities, increases its dependence on foreign manufacturers of high-tech products and components, and hinders innovations, since the scope of their application is narrowing. In this paper we've processed statistics to view the regional structure of the world's advanced manufacturing in dynamics. Such an analysis could be useful to track structural shifts that occur in the geographical location of innovative production over time, to identify countries and regions in which the advanced manufacturing industry is developing at a faster pace.

Keywords. Advanced manufacturing. Input-output analysis. Multi-regional input-output tables.

Definition of advanced manufacturing

In the scientific literature, there is a traditional reference to the definition of advanced manufacturing proposed in [1]: "a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology".

Another the most cited relevant result is an exact set of “top 50 industries that constitute the advanced industries sector” proposed by Muro, et al (2015) [2]. Among those industries 35 belongs to advanced manufacturing, including, for example, Aerospace Products and Parts, Communications Equipment, Computers and Peripheral Equipment, Resins and Synthetic Rubbers, Fibers, and Filaments, Pharmaceuticals and Medicine, etc. In categorization industries as “advanced”, the authors used 2 criteria: R&D spending exceeds 450 USD per worker, and over 21 percent of an industry’s workforce can be found in occupations requiring a high-degree of STEM knowledge. For operationalization purposes, it’s important that all 35 advanced manufacturing industries are defined by authors at the four-digit North American Industry Classification System (NAICS) code level.

Paying tribute to such an approach, we still see several problems with it.

First of all, it is based on and applies to the specifics of the US economy in 2014–2015. Whether it is fully applicable to other economies of the world and whether it is still relevant in relation to the values of the selection criteria is an open question. As a sub-problem one should remember about NAICS conversion to other systems – International Standard Industrial Classification of All Economic Activities (ISIC), Chinese Industry Classification System (GB/T 4754), United Kingdom Standard Industrial Classification of Economic Activities (UKSIC), Russian Economic Activities Classification System (OKVED), etc.

Another problem arises in relation to the nature of advanced manufacturing. It’s not about formal statistical grounds, it’s about engineering properties of products and technological processes. Traditional statistical classification wasn’t designed to fully grasp advanced manufacturing innovativeness. Under the same statistical category, one can have a variety of manufacturing activities, from rather “primitive” to highly “advanced”.

To our view, there is still no single one-fits-all approach when using traditional statistical data. To make an accurate measurement of advanced manufacturing we need additional primary data based on engineering expertise and not usually incorporated in existing official statistics. Under these circumstances, one should not be deceived by using sophisticated multi-item categorization scheme, because it doesn’t always mean more accurate analysis. Without primary engineering data, there is room only for describing tendencies in rather broad categories.

One example of a simple classification and a non-detailed approach can be found in (Richter et al., 2019). While using input-output methodology, the authors refer to advanced manufacturing such (rather high-level classified) industries as Primary metals, Fabricated metal products, Machinery, Computer and electronic products, Electrical equipment, appliances, and components, Motor vehicles, bodies and trailers, and parts, Other transportation equipment [3].

In further analysis for indirect estimations of advanced manufacturing, we use different sets of statistical entities due to data available (Table 1).

The problem of statistical analysis

Typically, statistical analysis uses indicators of the industry share in the GDP. For example, UN statistics shows the value added created in manufacturing as a percentage of GDP for each country [4]. Such an indicator in 2015, for example, was 10.5% for the UK, 11.7% for the US, 20.9% for Japan, 22.6% for Germany, 29.4% for China, 37.5% for Ireland. These figures reveal the sectoral structure of the analyzed economies, but they do not show the contribution of each country or a region to the global production of the given product. In addition, the UN statistics presents the entire manufacturing industry (see ISIC, section D), but not advanced manufacturing.

Table 1. This paper's categorization of advanced manufacturing industries

MRIO name	Industries
Eora	No 9 – Electrical and Machinery No 10 – Transport Equipment
WIOD	C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations C26 Manufacture of computer, electronic and optical products C27 Manufacture of electrical equipment C28 Manufacture of machinery and equipment n.e.c C29 Manufacture of motor vehicles, trailers and semi-trailers C30 Manufacture of other transport equipment
OECD-ICIO	D21 Pharmaceuticals, medicinal chemical and botanical products D26 Computer, electronic and optical equipment D27 Electrical equipment D28 Machinery and equipment, nec D29 Motor vehicles, trailers and semi-trailers D30 Other transport equipment

The regional structure of advanced manufacturing is described in reports of leading consulting companies. The report on the Global Industrial Machinery Industry describes this industry in details with the estimated volume of the world market of 566 billion USD in 2020 [5]. The structure of manufacturing output as a percentage of global production is given in the statistical reports of UNIDO [6]: in the third quarter of 2019, Europe accounts for 23.5% of global manufacturing output, North America takes 20,0% and China take 19,2%. HowMuch.net contains data on world's manufacturing output in 2019, according to which China produced by 4 trillion USD, the USA produced by 2,3 trillion USD and Japan earned 1,0 trillion USD [7]. Brookings' report "Global manufacturing scorecard: How the US compares to 18 other nations" provides data for 2015, according to which China produced goods worth 2 trillion dollars, which accounted for 20% of the global manufacturing industry, the share of the United States was 18%. According to the UN, however, in 2015, the value added of the manufacturing industry in China amounted to 3.2 trillion dollars, which differs from Brookings' estimates. Chinese value added in manufacturing was 3.9 trillion dollars in 2019, which is close to the estimates of HowMuch.net.

When comparing data from wide range of sources of information, one can notice various inconsistencies. It is not always clear which indicators are being compared: gross output or gross value added. The absolute and relative values of these indicators for the same period may differ in different sources. In addition, it is quite difficult to find statistics on individual products of the manufacturing industry that make up advanced manufacturing.

Authors propose to make statistical comparisons of data based on multi-regional input-output tables (MRIO), since the indicators in these tables are uniform. The names and the number of sectors (or products) for each economy is the same for a long period. The values of indicators of gross output, value added, final demand etc. are measured in the same money units for all countries, sectors and periods. Any MRIO is a model of global economy which is more or less balanced and consistent (though the data itself has flaws, the use of mathematical algorithms allows to make best possible estimates).

MRIO Eora, WIOD, OECD-ICIO: opportunities and limitations

A multi-regional input-output table is used primarily for measuring value added in trade, or degree of backward and forward integration within value chains, but it can also be used for cross-country comparisons of statistical indicators. The known MRIO covering a significant part of the world economy are: the World Input-Output Database (WIOD), the Global Trade Analysis Project database (GTAP), and the OECD-ICIO database. We have used also the data of another well-known multi-regional IO table - "Databases of the global supply chain Eora" [8, 9].

When choosing between Eora, WIOD and other multi-regional tables, we were guided by such considerations as coverage of the largest time interval for analysis, as well as the largest number of covered countries. According to these criteria, Eora was selected, in which data are presented for the period from 1990 to 2015. OECD-ICIO and WIOD provide data since 1995 and 2000 respectively. Eora is characterized by the most complete coverage of countries in the world, distinguishing 190 countries versus 43 economies in WIOD and 64 economies in OECD-ICIO.

The problem arising when using any MRIO, is unreliability of the data. The paper [10] provides information on the deviations of the indicators of various MRIOs from the data of the UN System of National Accounts, taken as a standard. The WIOD estimates of the GDP differ from the reference ones by ± 7%. For GTAP, the deviation of this indicator is more significant: for most economies it is underestimated by an average of 7%, but sometimes it differs from the benchmark by 12-14%. Domestic demand, exports and imports also differ from benchmarks, up to 40%, more often downward. Eora’s data accuracy is analyzed in the paper [11].

Methodology and results

In the selected version of MRIO, Eora26 [12], all economies are divided into 26 sectors (or products), based on the ISIC Rev. 3. Among 26 sectors used in Eora26, authors took N9 – Electrical and Machinery and No.10 – Transport Equipment. In our opinion, these are the sectors that make up advanced manufacturing or at least are the best approximation of it given the specifics of Eora 26.

When choosing indicators of statistical evaluation between gross output and gross value added, we selected gross (total) output. Our choice is due to the fact that modern innovative products include the services of third-party organizations (R&D, Software, other business services), the costs of which are not reflected in gross value added.

We used R language in RStudio IDE for working with Eora26 tables and Microsoft Excel to visualize final results. Data on advance manufacturing total output by country retrieved from Eora database was processed further by several simple procedures:

(a) Share of each country in the world advanced manufacturing total output in the respective year was calculated, thus giving the time series of such shares in 1990-2015.

(b) Four countries (former USSR, Armenia, Kazakhstan, Guyana) were deleted from the list because of obvious inaccuracies in the relevant data.

(c) All other economies were grouped in 4 regions of the world: North America, Europe, Asia and the Rest of the world. North America includes the United States and Canada, Europe includes all contemporary EU members, Asia includes all geographically Asian countries, with the exception of the republics of the former USSR.

(d) Countries were ranked by the average share in total output (averaged for the mentioned period).

(e) Top-7 countries were selected for special analysis and forecast.

(f) Forecast (simple linear trend) for these 7 countries was made for 2021-2022 based on Eora 26 data for 2010-2015 and World Development Indicators [13] data for 2016-2019.

Results of calculations in regional contribution to the global advanced manufacturing are shown in Figure 1.

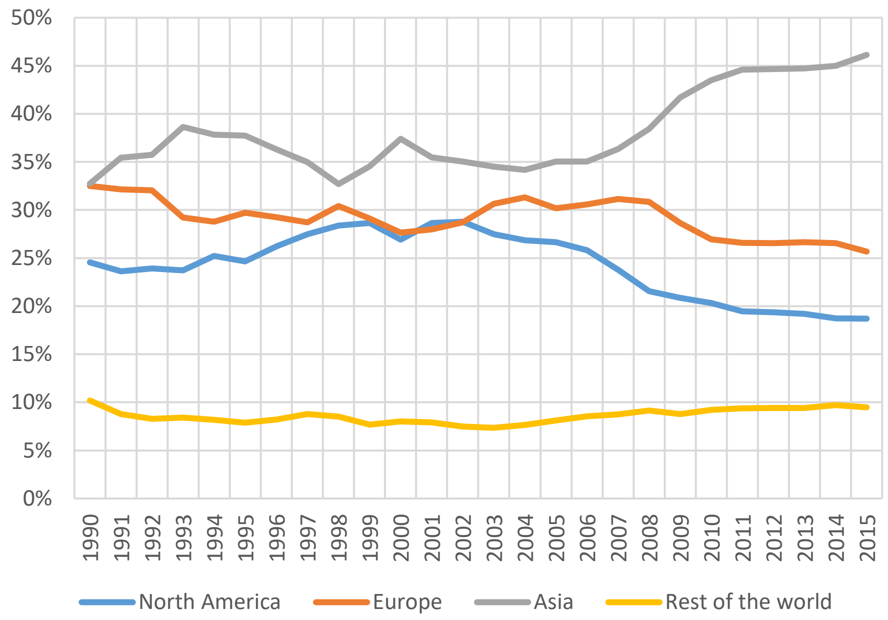

Figure 1. Dynamics of world advanced manufacturing total output at basic prices by region in 1990–2015
Source: Calculated by authors with data from MRIO Eora 26.

Results of forecasting for 2021-2022 and dynamics of total output by the top-7 countries during 1990–2019 are visualized in Figure 2.

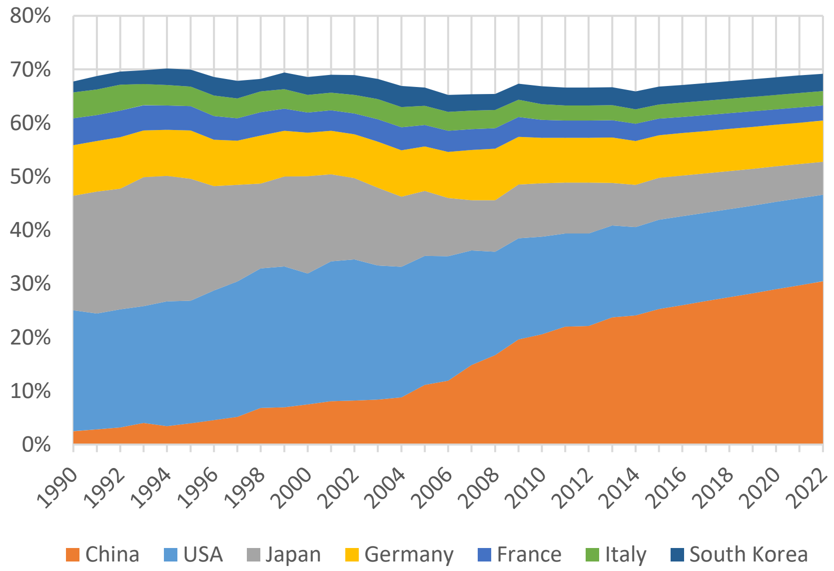

Figure 2. Dynamics of advanced manufacturing total output by country in 1990–2019 with forecast till 2022
Source: Calculated by authors with data from Eora 26 and World Development Indicators.

The growing role of China

From the analysis of Figure 2, the growing role of China is obvious. This role is even more noticeable when considering the share of intermediate consumption of products of advanced manufacturing within the country (domestic intermediate consumption) in relation to the world output of advanced manufacturing (Figure 3).

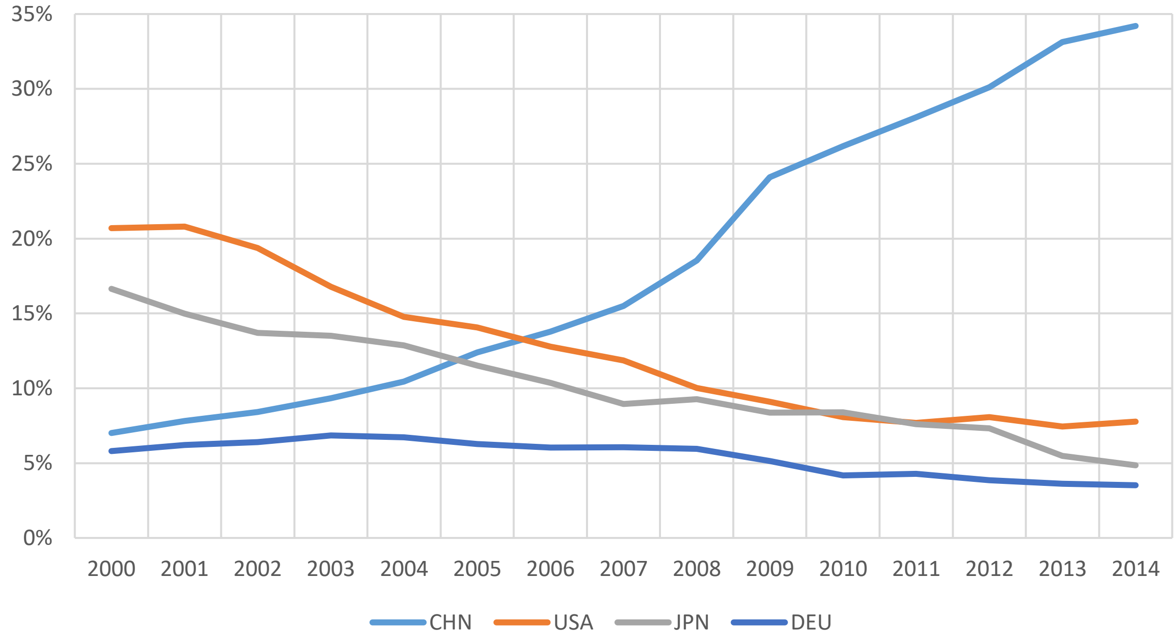

Figure 3. Dynamics of the share of domestic intermediate consumption to global intermediate consumption in advanced manufacturing
Source: Calculated by authors with data from OECD-ICIO.

In 2000, China's share was just over 5%, and already in 2014, it was almost 35%. This indicates that in the Chinese economy, national inter-industry chains in the field of high-tech industry have significantly developed and become more complex, and China has ceased to be just an assembly shop.

Using the approach described in the paper [14], according to the OECD-ICIO data, it is possible to calculate and visualize the dynamics of the contribution of individual industries to the trade balance, taking into account the added value they create (in exported goods and services) and the final and intermediate imported goods and services consumed in absolute terms (Figure 4).

As the analysis shows, despite China's significant success in advanced manufacturing, yet taking into account the final imports of knowledge-intensive products and the intermediate imports required for the functioning of such an industry, China still needs external goods and services.

However, a more detailed analysis shows (figure 5) that two industries have a stable positive contribution: Computer, electronic and optical equipment and Electrical equipment.

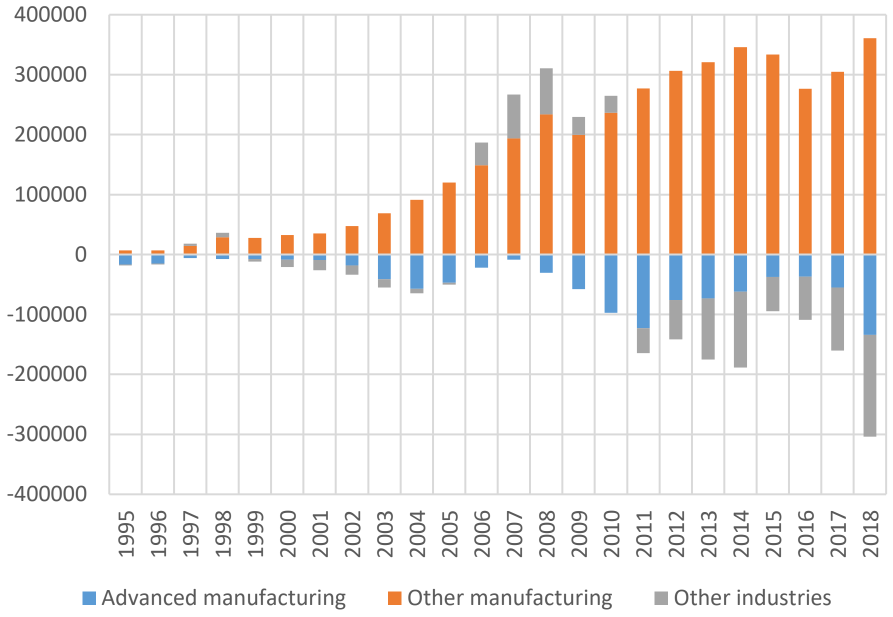

Figure 4. Dynamics of the contribution of individual industries to the trade balance, taking into account the added value they create and the imported goods and services consumed (thousands USD, absolute terms)
Source: Calculated by authors with data from OECD-ICIO.

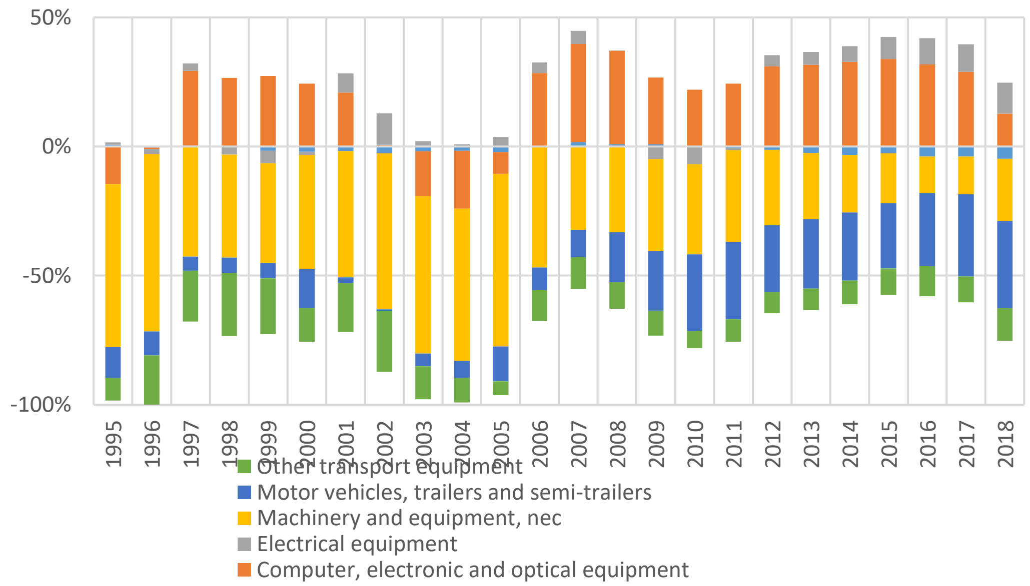

Figure 5. Dynamics of the structure the contribution of advanced manufacturing industries to the trade balance, taking into account the added value they create and the imported goods and services consumed
Source: Calculated by authors with data from OECD-ICIO.

Conclusions, discussion and future research

Until 2008, Europe and North America dominated in terms of output in the advanced manufacturing of the world. Japan and South Korea also made a significant contribution. After the 2008 global financial crisis, the situation changed dramatically, American and Japanese manufacturers began to lose market share, yielding to Asian manufacturers. China annually increased its share in the world market of advanced manufacturing products by almost 1%, Japan and the United States together lost 1% of this market annually.

In the short term, China remains the largest producer of electronics, machinery and equipment, and vehicles, as well as their most important exporter. The powerful industrial sector is a base for the innovative development of Chinese economy in the future.

MRIO databases are a handy statistical tool and data source for analyzing global production and markets. The accuracy of the given results needs additional verification, but as the MRIO data and methodology improves, accuracy will increase.

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ОПРЕДЕЛЕНИЕ СТРУКТУРЫ МИРОВОЙ НАУКОЕМКОЙ ПРОМЫШЛЕННОСТИ С ПОМОЩЬЮ МЕЖРЕГИОНАЛЬНЫХ ТАБЛИЦ ЗАПРОС-ВЫПУСК EORA, WIOD И OECD-ICIO

А. БЫКОВ
Д.э.н., профессор, проректор по научной работе БГЭУ

В. ПАРХИМЕНКО
К.э.н., доцент, заведующий кафедрой экономики БГУИР

В. ВЕРНЯХОВСКАЯ
Магистр экономики, заместитель декана инженерно-экономического факультета БГУИР

Белорусский государственный экономический университет, Республика Беларусь
Белорусский государственный университет информатики и радиоэлектроники, Республика Беларусь
Email: aliaksei.bykau@yandex.ru, parkhimenko@bsuir.by, verniahovskaya@bsuir.by

Аннотация. Будущее мировой экономики обычно связывают с развитием инновационного сектора, где человеческий капитал является основным фактором производства. Несмотря на общую тенденцию роста в сфере услуг, предпосылкой инновационного развития экономики остается сильная обрабатывающая промышленность, особенно в ее наиболее инновационной части, включая производство электроники, роботов, машин и оборудования, транспортных средств. Деградация производственных мощностей лишает национальную экономику возможностей роста, увеличивает ее зависимость от зарубежных производителей высокотехнологичной продукции и комплектующих, сдерживает инновации, поскольку сужается сфера их применения. В данной работе на основе данных межрегиональных таблиц «затраты - выпуск» делается попытка оценить региональную структуру наукоемкой промышленности в мире. Такой анализ может быть полезен для отслеживания структурных сдвигов, происходящих во времени в географическом размещении инновационных производств, для выявления стран и регионов, в которых опережающими темпами развивается наукоемкая промышленность.

Ключевые слова. Наукоемкая промышленность. Анализ «затраты - выпуск». Межрегиональные таблицы «затрат-выпуск».