

Development of ‘smart’ manufacturing in Russia: Empirical region-specific study of system technologies

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Abstract. The purpose of the paper is to consider the concept of Industry 4.0 through the prism of ‘Factories of the Future’ program as a system of integrated technological solutions for creating ‘smart’ industries. The paper analyzes the TechNet road map proposed by the National Technological Initiative, a program aiming at enhancing the global competitiveness of Russian industry by 2035. A region-specific empirical study focuses on system technologies that contribute to the development of ‘smart’ manufacturing in four industrial regions of Russia: Sverdlovskaya, Chelyabinskaya, Kurganskaya and Tumenskaya Oblasts. The conclusion is made about the upward trend in the development of ‘smart’ industries in Sverdlovskaya and Chelyabinskaya Oblasts.

1 Introduction

A territorial production system at any level can be viewed as a complex of technologies. All technologies can be conventionally categorized into basic, component, and system technologies [1-4]. Basic technologies are technologies for the production of materials and other substances (e.g., alloy used for manufacturing aircraft engine turbine blades). Component technologies are technologies for the production of components and subassemblies that are not products of final consumption (e.g., an aircraft turbine engine). System technology integrates component technologies to produce the final product for end users by developing highly engineered mechanisms, machines, and apparatuses (e.g., a passenger aircraft) [5].

Thus, system technologies and related component technologies are carriers of the most advanced technical solutions; accumulate the intellectual labor of thousands of people, research and development in the field of Advanced Manufacturing Technologies (AMT) which accumulate multidisciplinary knowledge and intellectual know-how [6].

A key feature of the current stage of technological development of territorial production systems is an overall change by digitalization and automation. The concept of Industry 4.0 as a set of technological changes in manufacturing was coined by the German government in 2011. The main paradigm for automation and data exchange in manufacturing technologies includes the use of the Cyber-Physical Systems which enable to connect the physical things with virtual models [7]. In Russia, the concept of digital transformation of the production

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sector through the development and implementation of AMT is applied within the framework of the National Technology Initiative (NTI), a program aiming at enhancing the global competitiveness of Russian industry by 2035 [8].

In this regard, we may hypothesize that a variety of system technologies and localization of system integrators in a region may testify that the processes of digital transformation of the domestic production sector and the development of Smart Manufacturing are taking place in Russian regions.

System technologies determine the production specialization and competitiveness of the region, since they offer opportunities to manufacture high-tech industrial products with high added value. At the same time, to ensure the implementation of system technologies, component technologies develop with a multiplicative effect. Component technologies may also contribute to gaining territorial competitive advantage by establishing new component manufacturing with a high level of employment based on the introduction of new engineering and manufacturing solutions and the development of new products. The development of basic technologies is largely due to the presence and composition of local mineral resource base. The growth of system technologies used in the region prompts the corresponding growth of component technologies. Thus, various technologies and localization of system integrators is a factor that maintains stability and competitiveness of regional industries. This results from possible engineering integration along global technological chains and visual effect of diversification: the territory retains its economic stability even if a product manufactured with the use of a particular technology is not in demand. On the contrary, the dominance of a technology (even if there are many system integrators) is the factor that makes regional economy more sensitive to market fluctuations.

The NTI TechNet roadmap introduces the concept of Factories of the Future (FoF), FoF are understood as systems of integrated technological solutions (in fact, integrated technological chains) that enable to design and manufacture a new generation of globally competitive products in the shortest possible time. The TechNet roadmap suggests a classification of FoF on the basis of leading groups of technologies: Digital Factories, Smart Factories and Virtual Factories. Digital Factories are charged with the task of designing manufactured products by using software, digital design and modeling tools. Smart Factories refer to flexible production facilities with a wide application of Process Automation Systems (PAS) and planning systems based on robotic processes. The combination of these technologies is aimed at increasing an overall level of intellectualization and production efficiency, increasing fault tolerance, and creating the basis for further development of new markets for innovative manufacturing solutions. Finally, Virtual Factories is an aggregator that connects all parties into a single logistics chain: consumers of high-tech products, manufacturers, designers and programmers of production software (Digital Factories), facilities for components production; assembly and final product manufacturing using the most advanced technologies (Smart Factories), as well as suppliers of materials. Creation and scale application of technological solutions proposed in the TechNet roadmap are aimed at developing and increasing the export potential of the domestic industry, as well as at resolving the issue of substituting imported high-tech products through the use of advanced production technologies [9].

It has been witnessed that some sectors of the Russian economy conform to international standards with regard to the degree of digitalization (e.g., finance, state and municipal services, education). At the same time, the manufacturing sector cannot meet the international standards of digitalization and application of advanced technologies. Nevertheless, in recent years many regions have started modernizing the existing production facilities and building new 'smart' capacities which integrate computer high-precision and information components with high-performance labor and create cooperative chains, territorial manufacturing and technological clusters. Surveys show that 78% of Russian large companies' management

consider digital transformation to be their priority for the next 3-5 years, which certainly gives grounds for optimistic forecasts of the manufacturing sector growth in Russia in Industry 4.0 [10].

2 Methods and results

An empirical study of system technologies was conducted for four legal entities within the Ural Federal Okrug: Sverdlovskaya Oblast, Chelyabinskaya Oblast, Kurganskaya Oblast and Tyumenskaya Oblast (autonomous okrugs excluded). The choice of the manufacturing sector as the subject of study is determined by the pronounced industrial type of these regions' economies: a significant share of the gross regional product is formed by processing industries.

To identify the totality of technologies implemented in the regions, disaggregation of the Russian National Classifier of Types of Economic Activity (OKVED-2) codes has been applied. We understand a type of economic activity as a combination of similar technologies, which results in a final product or a product for intermediate consumption. Given this provision, we have detailed the OKVED-2 codes to the level of a single technology. For example, production of air and space craft and related equipment (OKVED-2 code 30.3) includes system technologies (manufacturing of aircraft; helicopters; unmanned systems and flight hardware; launch test vehicles; artificial satellites, planetary probes, orbital stations, shuttles etc.) and component technologies (production of components for aerial vehicles; fuselages, wings, doors, pitch attitude control fins; control wheels; chassis, fuel tanks; open cockpits; aircraft motors and engines; components for turbojet and turboprop aircraft; equipment for launch complexes for rockets and spaceship).

The sample includes three types of companies: system technology integrators; component technology integrators; and basic technology integrators. Technological affiliation of the company was determined by its core economic activity. SPARK-Interfax was used to verify the study sample (Table 1). The observation period is 12 years, from 2007 to 2019.

Table 1. The study sample (2019)

Factor	Kurganskaya Oblast	Tumenskaya Oblast*	Sverdlovskaya Oblast	Chelyabinskaya Oblast
General totality (<i>N</i>)	290	541	1673	1468
Sample companies (<i>N</i>)	144	255	865	859
Aggregated market share by profit (%)	85.5	83.6	86.0	86.3
Identified basic technologies (<i>n</i>)	8	12	37	31
Identified component technologies (<i>n</i>)	26	38	101	86
Identified system technologies (<i>n</i>)	8	11	72	24

*Autonomous okrug excluded

The next step was to calculate Shannon and Simpson indices for each region, which are used to measure diversity of objects in a limited population (Table 2). Shannon Index (Eq. 1) characterizes the diversity and alignment of objects in the population. Simpson Index (Eq. 2)

indicates the dominance of certain objects in the aggregate. The combination of these indices is believed to most fully characterize the measure of diversity [11].

$$H = - (p_i/p \cdot \ln (p_i/p)) \tag{1}$$

$$D = (\sum p_i (p_i-1)) / p(p-1) \tag{2}$$

where $p_i = i$ technology integrators;

p = total companies;

n = total technologies by type

The obtained data can be interpreted as follows:

1) The more technologies in the region's industrial sector and the less variable the number of the companies integrating these technologies, the higher Shannon Index. With a small diversity of technologies, Shannon Index tends to zero.

2) The more pronounced the dominance of a technology (see number of technology integrators), the higher Simpson Index. With a uniform distribution of technology integrators, Simpson Index tends to zero.

Table 2. Calculated Shannon and Simpson Indices

<i>Shannon Index</i>				
	2007	2011	2015	2019
Sverdlovskaya Oblast	5.01	6.12	5.78	5.81
Tumenskaya Oblast*	3.36	3.40	3.67	4.32
Chelyabinskaya Oblast	5.36	5.61	5.62	5.69
Kurganskaya Oblast	3.58	3.50	3.51	3.33
<i>Simpson Index</i>				
Sverdlovskaya Oblast	0.112	0.110	0.091	0.084
Tumenskaya Oblast*	0.43	0.41	0.32	0.36
Chelyabinskaya Oblast	0.093	0.092	0.097	0.081
Kurganskaya Oblast	0.21	0.22	0.27	0.28

*Autonomous okrug excluded

According to the 2019 data, most system technologies were used in Kurganskaya Oblast (19% of the total), followed by Tumenskaya Oblast (18%) and Chelyabinskaya Oblast (17%). The share of system technologies implemented in Sverdlovskaya Oblast was the lowest and accounted for 14%. However, the number of implemented system technologies has been increasing steadily in Sverdlovskaya and Chelyabinskaya Oblasts, as can be seen in Fig. 1.

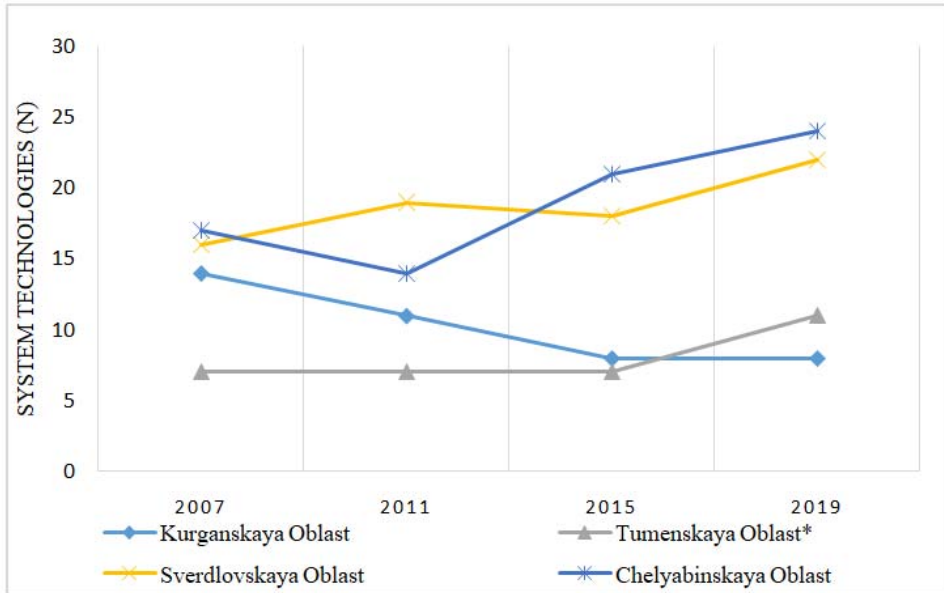


Fig. 1. System technologies implemented in the studied regions.

For each group of companies Total Factor Productivity was found. It measures productivity growth and has become a proxy for technological progress. A state-of-the-art measure of TFP is given by the following formula (Eq.3):

$$TFP = (Y/K)^{\alpha} / (1 - \alpha) \quad (3)$$

where Y = total output;
 K = capital input;
 L = labour input;
 A = total factor productivity;
 α = perspective share of output (= 0.3).

3 Discussion

By and large, diversity indices for Sverdlovskaya and Chelyabinskaya Oblasts are comparable in terms of value and show a similar trend toward an increasing diversity of technologies. A number of system integrators in these two regions is growing. Currently, 144 system integrators are located in Sverdlovskaya Oblast (Fig. 2) and 132 in Chelyabinskaya Oblast. However, at all technological levels we observe the smallest variance of TFP, which indicates a low fragmented inter-firm environment. A free flow of resources contributes to more even distribution and localization of technologies in the most productive companies.

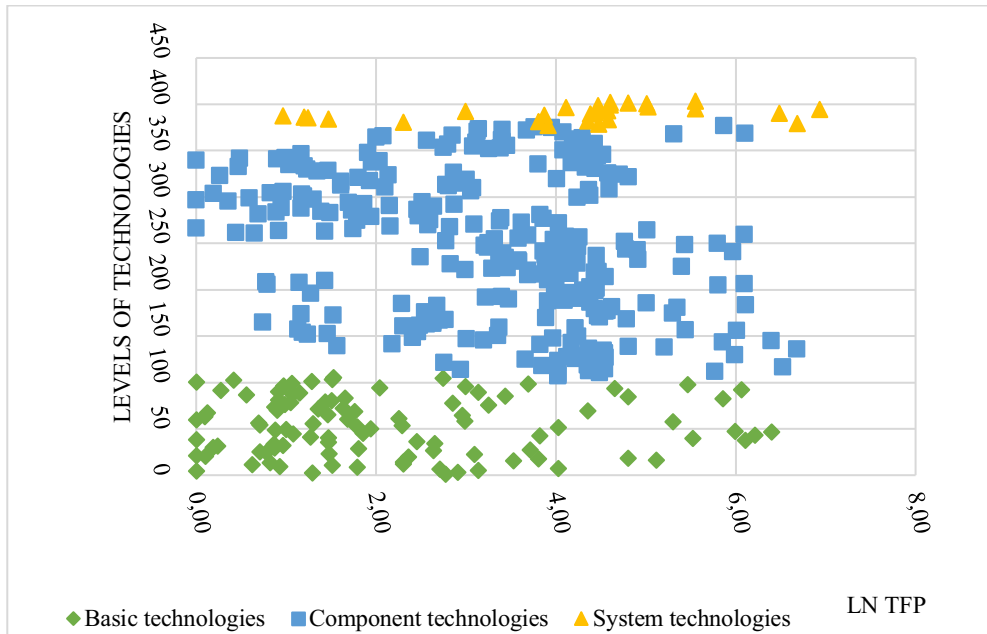


Fig. 2. TFP of firms located in Sverdlovskys Oblast (2019)

As it was expected, the manufacturing sector of Tumenskaya Oblast has the highest Simpson index, which proves the presence of the dominant technology that forms a vector of development of the regional manufacturing sector and reduces its resistance to market fluctuations. The component integrator group includes the firms producing constitutive elements for the dominant system technology. However, we can observe a downward change in Simpson Index, which indicates that other system and component technologies emerge in the region. It is worth noting that during the entire observation period, system integrators in Tumenskaya Oblast showed the highest TFP.

Kurganskaya Oblast is also characterized by high Simpson Index and low values of Shannon Index. This proves a small variety of technologies and the presence of a dominant technology. However, on the one hand, a downward trend is observed since the range of technologies is narrowing. On the other hand, component technologies do not match the profile of system technology. This exacerbates a reduction in gross value added, generated by system integrators.

For Tumenskaya, Sverdlovskaya and Chelyabinskaya Oblasts TFP in the group of system integrators is higher than in the groups of basic technology and component integrators. TFP levels in Kurganskaya Oblast are comparable along all three groups and are similar to basic technology productivity in Chelyabinskaya and Sverdlovskaya Oblasts. In general, system technologies create higher added value.

However, we argue that the more system technologies implemented in the region, the greater the gap in TFP levels in the system and component technologies. The variety of technologies in the system and component groups contributes to higher gross value added generated by system integrators.

4 Conclusions

Thus, the analysis of technological development of the manufacturing sectors and the establishment of system integrators in four regions of Russia shows that the most dynamic processes of creating 'smart' industries based on system technologies take place in Sverdlovskaya and Chelyabinskaya Oblasts. Localization of system integrators in these regions, a significant variety of system technologies and, as a result, the formation of supporting groups of component technologies, provide multiplicative integrated development of the industrial sector in these regions based on scaling up modern 'smart' industries. This smart manufacturing can generate high added value, which, in turn, might attract

additional funds and high-skilled human resources. This will ensure economic stability and a high level of regional competitiveness.

References

1. C.W.I. Pistorius, J.M. Utterback, *Research Policy*, **26 (1)**, 67 (1997)
2. N. Meade, T. Islam, *Management Science*, **44(8)**, 1115 (1998)
3. S.J. Lee, D.J. Lee, H.S. Oh, *Technological Forecasting and Social Change*, **72 (8)**, 1044 (2005)
4. G. Zhang, D.A. McAdams, V. Shankar, M.M. Darani, *Technological Forecasting and Social Change*, **125**, 116 (2017)
5. G. Zhang, D. Allaire, V. Shankar, D.A. McAdams, *PLoS ONE*, **14(6)**, e0218370 (2019)
6. N.V. Vasilenko, K.V. Kudryavtseva, Digital transformation of the economy and industry: problems and prospects, 67 (2017)
7. S.I. Tay, T.C. Lee, N.A.A. Hamid, A.N.A. Ahmad. *Jour of Adv Research in Dynamical & Control Systems*, **10 (14)**, 1379 (2018)
8. A.V. Babkin, D.D. Burkaltseva, D.G. Kosten, Yu.N. Vorobiev. *Scientific and technical statements of the St. Petersburg State Polytechnic University. Economic sciences*. **3 (10)**, 9 (2017)
9. I.A. Gunina, E.V. Shkarupeta, V.V. Reshetov, Innovative clusters of the digital economy (2018)
10. I.N. Tkachenko, E.N. Starikov, *Izvestiya of Saratov University. New series. Series: Economics. Management. Law*, **3(20)**, 244 (2020)
11. M.V. Evseeva, *Journal of New Economy*, **3(21)**, 132 (2020)