“Developing the intra-firm technology transfer system at the industrial enterprise based on matrix approach”

AUTHORS	Olga Maslak Natalia Grishko Kateryna Vorobiova Olha Hlazunova Maria Maslak

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Olga Maslak, Doctor of Economics, Professor, Head of economics department, Kremenchuk Mykhailo Ostrohradskyi National University, Ukraine.

Natalia Grishko, Ph.D. in Economics, Senior Lecturer of economics department, Kremenchuk Mykhailo Ostrohradskyi National University, Ukraine.

Kateryna Vorobiova, Ph.D. in Economics, Senior Lecturer of economics department, Kremenchuk Mykhailo Ostrohradskyi National University, Ukraine.

Olha Hlazunova, Ph.D. in Economics, Senior Instructor of economics department, Kremenchuk Mykhailo Ostrohradskyi National University, Ukraine.

Maria Maslak, Lecturer of the department of Management of organization, National Technical University "Kharkiv Polytechnic Institute", Ukraine.

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Olga Maslak (Ukraine), **Natalia Grishko** (Ukraine), **Kateryna Vorobiova** (Ukraine), **Olha Hlazunova** (Ukraine), **Maria Maslak** (Ukraine)

DEVELOPING THE INTRA-FIRM TECHNOLOGY TRANSFER SYSTEM AT THE INDUSTRIAL ENTERPRISE BASED ON MATRIX APPROACH

Abstract

It is proved that the modern level of economy competitiveness has been achieved due to the scientific and technical innovations in the industrial sphere. Given the global trends, Ukraine is working out its own direction of the innovative development. To achieve the final result of innovation at the industrial enterprises, it is necessary to ensure a transfer of innovative technologies to the commercial production. Shift of the technological developments from the research units to the potential customers is usually brought about with the help of market mechanisms, i.e., launching the technologies into the market and its promotion. The article offers a matrix approach to determine the overall development of intra-firm technology transfer system considering both the internal innovation capacity and favorable external conditions. The general scheme for determining the capacity of intra-firm technology transfer system development at machine-building enterprise on the basis of correlation and regression modeling has been developed. Four main program of developing the intra-firm technology transfer system are offered. They include active development which stipulates the extensive use of endogenous factors in terms of favorable environment; moderate growth which is appropriate given certain internal and external problems of enterprises innovative development in general and technology transfer systems in particular; anti-crisis development which is appropriate either in terms of favorable environment given low internal capacity of technology development and transfer or in a difficult situation at macro-level given high transfer potential; "cryogenic" period when the entity is suffering a crisis and there are a lot of external risks, it is reasonable to resort to the "deliberate damping", being forced to suspend the innovative activity, creation and development of technology transfer system. Scientific and practical recommendations are provided to develop the intra-firm technology transfer system of the leading machine-building enterprises in Poltava region, such as PJSC "Kremenchug Plant of Road Machines", PJSC "Kryukov Railway Car Building Works", PJSC "Kremenchug Wheel Plant", PJSC "AutoKrAZ".

Keywords intra-firm technology transfer, matrix approach, correlation and regression model, favorable external environment, direction of technology transfer development, cumulative effect of the technology transfer

JEL Classification O14, O30, O31, O34

INTRODUCTION

Intra-firm technology transfer potential of the enterprise can be determined based on the level of internal and external potential transfer, the main components of which are technological, organizational, human, market, fixed and financial assets. Development of intra-firm technology transfer system is to be considered in the context of strategic management; the objective of effective implementation is to improve technical and technological state of the entity in order to achieve and enjoy technical advantages, thanks to which the company will be able to respond adequately to the requests and demands of the market, producing a competitive product manufactured with the help of one's own technology.

Considering both the internal innovation capacity (entity's state of readiness to innovate and transfer the ideas and inventions) and favorable external conditions (level of development and stability of the legal rules and regulations in this area, demand for modernized and innovative products, great investment and innovation infrastructure, financial stability, industrial cooperation with research centers, state support of innovative enterprises, etc.) is required to determine the overall development of intra-firm technology transfer system. To evaluate the internal efficiency of technology transfer at the enterprise, it is necessary to consider a wide range of criteria with all their complexity and systemic nature. We believe that the intra-firm technology transfer system on the grounds of intrapreneurship leads to the following results: increasing innovation activity of the enterprise $\left(I_{ac}\right)$, increasing the efficiency of production and technical facilities $\left(I_{p-t}\right)$, improving financial performance $\left(I_{fp}\right)$, investment and innovation performance $\left(P_{i-inov}\right)$, innovative staff $\left(I_{st}\right)$, marketing $\left(E_M\right)$, communication $\left(E_C\right)$ and environmental efficiency $\left(E_{env}\right)$. To determine the cumulative effect of intra-firm technology transfer, one should take into account the importance of each result determined by expertise given the specific nature of the industry:

$$E_K = 0.15 \cdot I_{ac} + 0{,}16 \cdot I_{p-t} + 0.14 \cdot I_{fp} + 0.15 \cdot P_{i-innov} + 0.14 \cdot I_{st} + 0.11 \cdot E_M + 0.08 \cdot E_C + 0.07 \cdot E_{env}. \quad (1)$$

Identification of the direction for entity intra-firm technology transfer system development includes the following stages (Figure 1):

- forming the performance indicator system reflecting the potential internal capabilities of developing the technology transfer system at enterprises;
- determining the most important indexes for a particular company based on the construction of nonlinear multivariate regression models;
- defining the overall development of the entity technology transfer system by comparing its internal capacity and favorable external conditions.

By analyzing and organizing the domestic and foreign sources concerning the given issues, the internal capacity performance indicator system has been identified for intra-firm technology transfer system development at machine-building enterprise:

- fixed assets renovation ratio is a partial indicator of industrial and technological capabilities of the entity that demonstrates the efficient equipment, its ability to produce modern and innovative products;
- autonomy ratio which shows the level of financial dependence of the company, the possibility of self-innovation and technology transfer development;
- coverage ratio is an overall liquidity indicator which demonstrates the ability to cover the short-term liabilities by current assets (most easily accumulated);
- products updating ratio which reflects the share of new and modernized products;
- inventory turnover ratio which shows the stock turnover over the given period and allows detecting the increased production stock;
- number of workers, who improved their skills in the current period, reflects the level of personnel skills and capacity for creative, innovative activities;
- financial sustainability factor which reflects the correlation between the own and borrowed funds invested in the business, describes the company's ability to attract external funding for active intra-firm technology transfer innovation and development;
- capitalization rate which allows evaluating the policy of profit distribution, shows the level of net profit reinvestment and its ability to intensify production and sales activities for its own account;
- economic growth stability factor which demonstrates the importance of net profit in ensuring the equity sustainable growth, shows the stability in increasing their own funding from retained earnings and capital reserve;
- operating assets ratio which reflects the share of the equipment suitable for use in production, demonstrates the real productive capacity of the enterprise;

Source: personal idea.

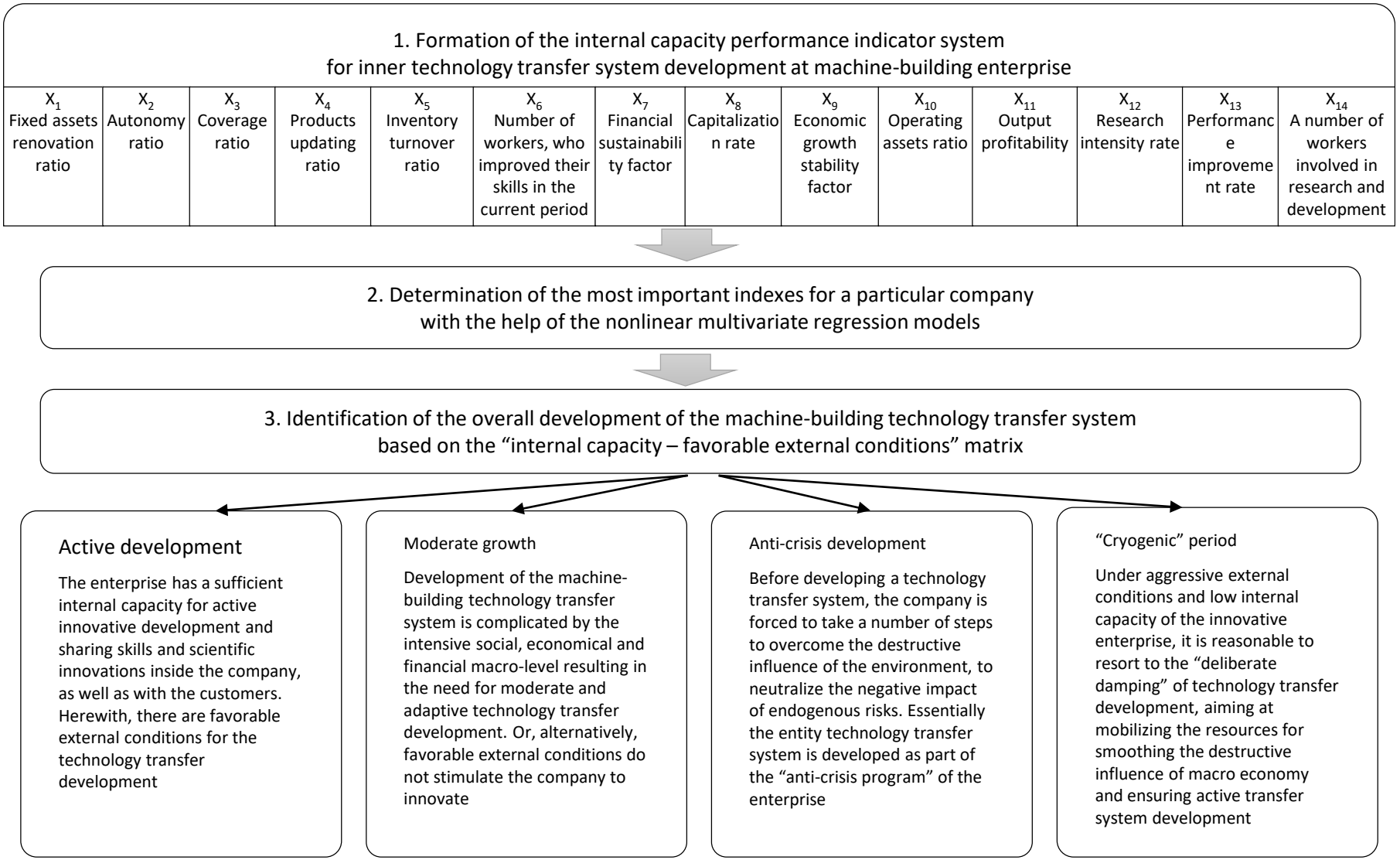

Figure 1. Procedure for determining the capacity for intra-firm technology transfer system development at machine-building enterprise

- output profitability;
- research intensity rate characterizes the effectiveness of innovation, namely the enterprise capacity to conduct research and development;
- performance improvement rate which demonstrates the dynamics of motivation efficiency in the company, further automated production;
- a number of workers involved into research and development.

1. DATA ABALISIS

To determine the most influential factors for a particular company, it is reasonable to use a correlation and regression analysis, which will define the relationship between technology transfer cumulative effect and the internal capacity of technology transfer system development at the enterprise. We used STATISTICA 10, software which simplifies the calculations.

In order to test the adequacy of correlation and regression models, F -test is used, which means F – distribution under the null hypothesis about statistical insignificance of regression which is discarded when performing such a condition: $F_{calculation} > F_{rate}$, where F_{rate} is determined by F – distribution table (two degrees of freedom: $k_1 = m,\ k_2 = n - m - 1$ and a given probability level α).

Evaluation of equations parameters for multiple regression can be made with the help of Student's t -test: $t_{calculation} > t_{rate}$ demonstrates the regressors value.

The correlation and regression results for the companies considered in the thesis (PJSC "Kremenchug Plant of Road Machines", PJSC "Kryukov Railway Car Building Works", PJSC "Kremenchug Wheel Plant", PJSC "AutoKrAZ") are given in Tables 1-4. Table 1 presents the regression values, as well as statistical significance of regression models for internal capacity of technology transfer system development at PJSC "Kremenchug Plant of Road Machines".

As you can see from the Table 1, the dynamics of the technology transfer cumulative effect at PJSC "Kremenchug Plant of Road Machines" is 98.71% predetermined by the dynamics of autonomy ratio, coverage ratio, inventory turnover ratio, financial

Table 1. Correlation and regression model of the internal capacity of technology transfer system development at PJSC "Kremenchug Plant of Road Machines"

Source: calculated by the authors.

PJSC "Kremenchug Plant of Road Machines"	Parameters	Standard error	$t(5)$, $t_{table} = 2.57$	p
Absolute term – X_0	–0.35654	0.446487	–0.79855	0.460781
X_2 (autonomy ratio)	–1.28538	0.259346	–4.95624	0.004262
X_3 (coverage ratio)	0.20270	0.046400	4.36858	0.007232
X_5 (inventory turnover ratio)	0.04028	0.006419	6.27498	0.001509
X_7 (financial sustainability factor)	–0.11364	0.034004	–3.34179	0.020512
X_9 (economic growth stability factor)	0.97672	0.198987	4.90847	0.004442
X_{10} (operating assets ratio)	3.15350	1.090496	2.89181	0.034115
Regressive statistics	Multiple correlation coefficient $R = 0.9871$	Coefficient of determination $R^2 = 0.9743$	Standard $R^2 = 0.9436$	Approximation error = 0.02791
$F_{calculation}(6,\ 5) = 31.647$	$F_{table}(6,\ 5) = 4.95$			

Source: produced by the authors.

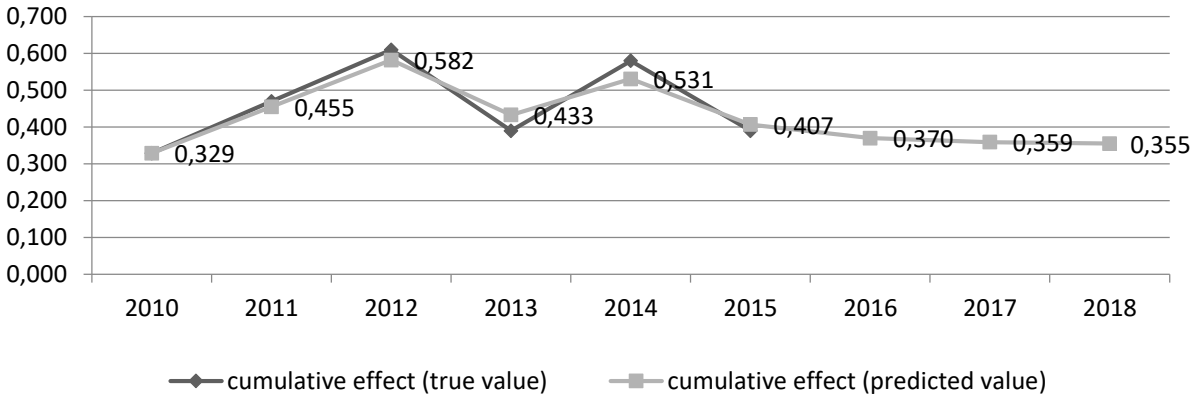

Figure 2. The dynamics of the predicted value for the cumulative effect at PJSC "Kremenchug Plant of Road Machines"

sustainability factor, economic growth stability factor and operating assets ratio.

In this case, the regression equation for the given enterprise is as follows:

$$Y = -0.356 - 1.285 \cdot X_2 + 0.203 \cdot X_3 + \\ +0.04 \cdot X_5 - 0.114 \cdot X_7 + 0.977 \cdot X_8 + \\ +3.154 \cdot X_{10}. \quad (1)$$

The equation results can be proved by F-test and Student's t-test, the approximation error is within the norm (up to 10%). With the help of the equation (1), we calculated the predicted value for the cumulative effect at PJSC "Kremenchug Plant of Road Machines" (Figure 2).

As you can see from Figure 1, transfer at PJSC "Kremenchug Plant of Road Machines" cannot be regarded as a positive process, but there is no drastic deterioration in the innovative activity observed.

As to PJSC "Kryukov Railway Car Building Works", the effectiveness of its technology transfer system is mostly predetermined by the dynamics in economic growth stability factor and operating assets ratio (Table 2). In this case, only three parameters are needed to calculate the cumulative effect which is simplified significantly, compared with the results of PJSC "Kremenchug Plant of Road Machines", where 6 basic parameters have been used.

Table 2. Correlation and regression model of the internal capacity of technology transfer system development at PJSC "Kryukov Railway Car Building Works"

Source: calculated by the authors.

PJSC "Kryukov Railway Car Building Works"	Parameters	Standard error	$t(8)$, $t_{table} = 2.306$	p
Absolute term – X_0	0.017452	0.022915	0.76162	0.468144
X_1 (fixed assets renovation ratio)	0.722356	0.193747	3.72834	0.005802
X_8 (capitalization rate)	0.095979	0.014335	6.69565	0.000153
X_{11} (output profitability)	2.364788	0.142126	16.63866	0.000000
Regressive statistics	Multiple correlation coefficient $R = 0.992$	Coefficient of determination $R^2 = 0.984$	Standard $R^2 = 0.978$	Approximation error = 0.03091
$F_{calculation}(3,\ 8) = 165.24 \quad F_{table}(3,\ 8) = 4.07$				

Table 3. Correlation and regression model of the internal capacity of technology transfer system development at PJSC "Kremenchug Wheel Plant"

Source: calculated by the authors.

PJSC "Kremenchug Wheel Plant"	Parameters	Standard error	$t(8)$, $t_{table} = 2.306$	p
Absolute term – X_0	–0.319182	0.096578	–3.30492	0.010780
X_3 (coverage ratio)	0.163329	0.048514	3.36661	0.009835
X_7 (financial sustainability factor)	–0.058559	0.024681	–2.37264	0.045061
X_{11} (output profitability)	2.368380	0.366736	6.45800	0.000197
Regressive statistics	Multiple correlation coefficient $R = 0.9438$	Coefficient of determination $R^2 = 0.8908$	Standard $R^2 = 0.8498$	Approximation error = 0.03950
$F_{calculation}(3,\ 8) = 21.755 \quad F_{table}(3,\ 8) = 4.07$				

In this case, the regression equation for the given enterprise is as follows:

$$Y = 0.017 + 0.722 \cdot X_1 + \\ +0.096 \cdot X_8 + 2.365 \cdot X_{11}. \quad (2)$$

Interdependence of the factors is grounded by the high correlation amounting to 0.9656, and 93.3% resulting index (technology transfer cumulative effect) can be explained by the dynamics of equation regressors.

With the help of equation (2), we calculated the predicted value for the cumulative effect at PJSC "Kryukov Railway Car Building Works" (Figure 3).

Data analysis of Figure 3 indicates the presence of negative trends in transfer at PJSC "Kryukov Railway Car Building Works" within last 3-4 years.

The dynamics of predicted values says that in the coming years the situation will not improve, although further cumulative effect value falling is not observed.

Cost-effectiveness of the intra-firm technology transfer system PJSC "Kremenchug Wheel Plant" to the great extent depends on autonomy ratio, financial sustainability factor and economic growth stability factor which determine the resultant dispersion index by 75.65%.

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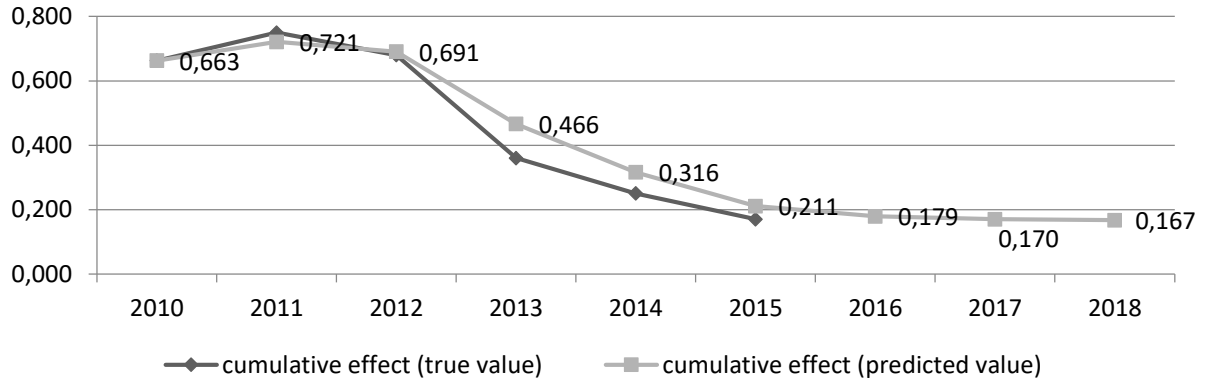

Figure 3. The dynamics of the predicted value for the cumulative effect at PJSC "Kryukov Railway Car Building Works"

Source: produced by the authors.

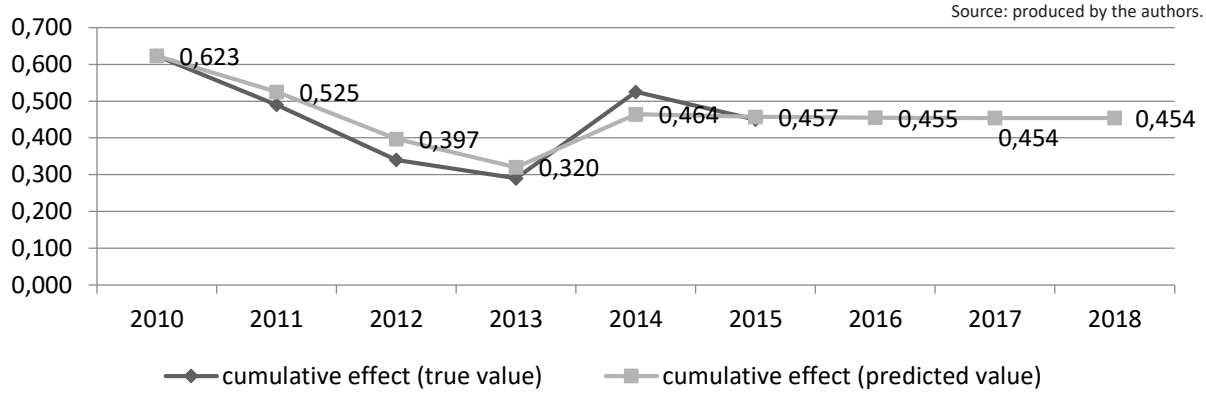

Figure 4. The dynamics of the predicted value for the cumulative effect at PJSC "Kremenchug Wheel Plant"

Other factors investigated do not have a great impact. The results of the given research are shown in Table 3. In this case, the regression equation for the internal capacity of technology transfer system is as follows:

$$Y = -0.319 + 0.163 \cdot X_3 - \\ -0.058 \cdot X_7 + 2.368 \cdot X_{11}. \quad (3)$$

Statistical evaluation of the resulting model shows that it is adequate and can be used to predict, as it fulfils the condition $F_{calculation} > F_{rate}$ and Student's t-test for all regressors (Table 3).

With the help of equation (3), we calculated the predicted value for the cumulative effect at PJSC "Kremenchug Wheel Plant" (Figure 4).

Analysis of the predicted values for the cumulative effect at PJSC "Kremenchug Wheel Plant" shows more optimistic results in the field of inner transfer activity at the plant. There are some improvements to overcome the crisis of 2011–2013. But there is still a need to make every possible effort to ensure the innovative development for the forecast period.

As our study reveals, the intra-firm technology transfer system at PJSC "AvtoKrAZ" is essentially dependent on the autonomy ratio, a number of workers, who improved their skills in the current period, economic growth stability factor. The results and calculations are given in Table 4.

Table 4. Correlation and regression model of the internal capacity of technology transfer system development at PJSC "AutoKrAZ"

Source: calculated by the authors.

PJSC "AutoKrAZ"	Parameters	Standard error	$t(7)$, $t_{table} = 2.365$	p
Absolute term – X_0	0.39770	0.198089	2.00767	0.084656
X_2 (autonomy ratio)	–3.50107	0.569668	–6.14580	0.000469
X_3 (coverage ratio)	0.75366	0.186329	4.04480	0.004903
X_9 (economic growth stability factor)	0.47340	0.099307	4.76698	0.002043
X_{12} (research intensity rate)	0.05949	0.018313	3.24836	0.014089
Regressive statistics	Multiple correlation coefficient $R = 0.9337$	Coefficient of determination $R^2 = 0.8719$	Standard $R^2 = 0.7987$	Approximation error = 0.06870
$F_{calculation}(4, 7) = 11.914$ $F_{table}(4, 7) = 4.12$				

Source: produced by the authors.

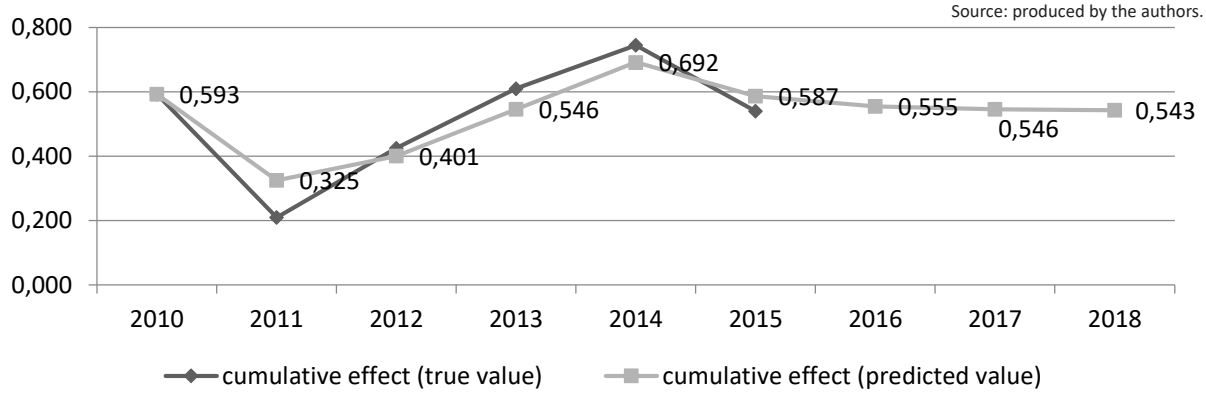

Figure 5. The dynamics of the predicted value for the cumulative effect at PJSC "AutoKrAZ"

So, the regression equation for the internal capacity of technology transfer system at the given enterprise is as following:

$$Y = 0.398 - 3.501 \cdot X_2 + 0.754 \cdot X_3 + \\ +0.473 \cdot X_9 + 0.059 \cdot X_{12}. \quad (4)$$

Data in Table 4 show that the factors of the resulting model are interconnected based on the high multiple correlation coefficient (0.8578), the resulting index (technology transfer cumulative effect) is stipulated by the equation regressors to 73.59%, as the coefficient of determination shows. With the help of equation (4), we calculated the predicted value for the cumulative effect at PJSC "AutoKrAZ" (Figure 5).

On the basis of data analysis of Figure 5, we may conclude that in 2014–2015, PJSC "AvtoKrAZ" succeeded in overcoming the financial crisis of 2011. But the political crisis in Ukraine in 2014–2015 adversely affected the continuation of these processes. In the forecast period, we will likely see the attempts of stabilizing the economic situation.

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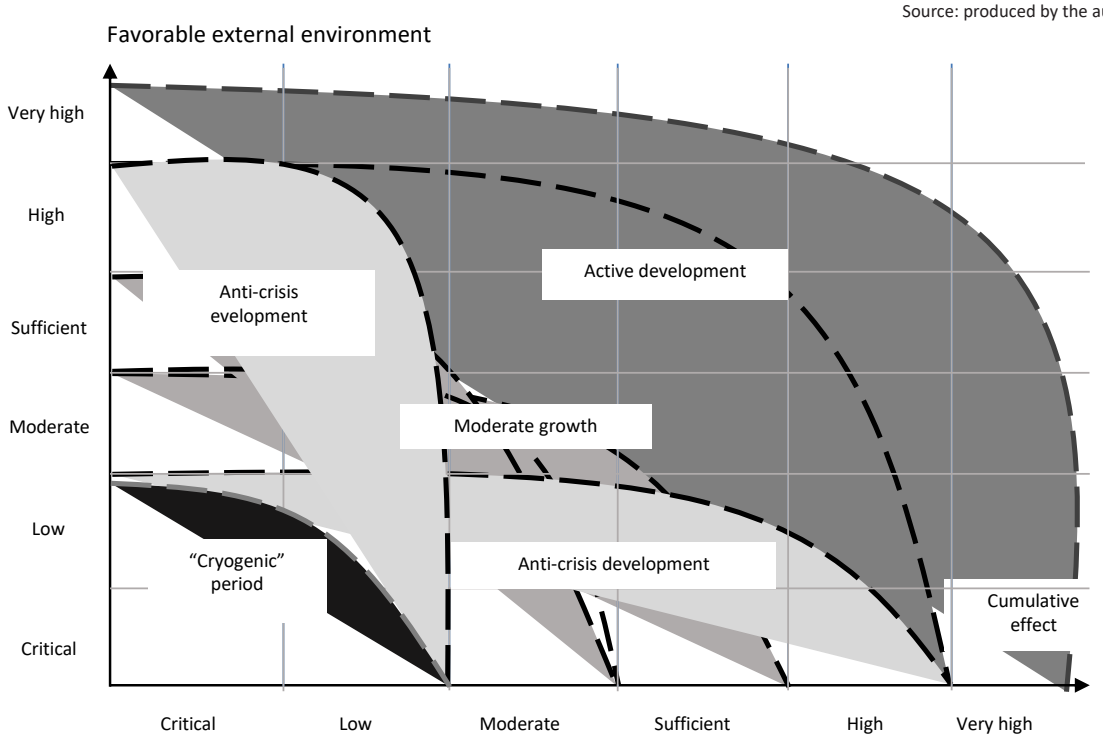

Figure 6. Matrix "internal capacity – favorable external environment" for defining the direction of technology transfer system development

The next step in determining the direction of technology transfer development at the machine-building enterprise is to compare the internal capacity of the entity to develop and transfer the innovative technologies and the favorable external environment. For this purpose, we propose to use a matrix of "internal capacity – favorable external environment" (Figure 6), which allows to identify the direction of technology transfer development under current economic conditions.

RECOMMEDATIONS

To achieve the practical purpose of the given article, the machine-building transfer activity is divided into four stages:

- active development which stipulates the intensive use of endogenous factors in terms of favorable external environment. Macroeconomics is characterized by suitable conditions for innovative activity of the economic entities as it has fixed legal rules and regulations in this area, considerable government support, favorable financial and economic factors, well-developed investment and innovation infrastructure, etc. So, having sufficient transfer capacity, stable financial position, high level of economic security, it is reasonable for the enterprise to develop the technology transfer by means of creating sustainable organizational and economic mechanism of technology development and transfer, creating and improving a technology transfer center, cooperating with external customers from research centers to innovate;

- moderate growth which is appropriate when there are some internal and external problems in the sphere of innovation in general and in technology transfer system in particular. In this case the macroeconomics poses a number of threats to the enterprise development, lack of innovative development support and, at the same time, inner transfer potential is at an acceptable level;

- anti-crisis development which is appropriate in terms of favorable environment given low internal capacity of technology development and transfer, or in a difficult situation at macro-level given high transfer potential;

- "cryogenic" period when the entity is suffering a crisis and there are a lot of external risks, it is reasonable to resort to the "deliberate damping", being forced to suspend the innovative activity, creation and development of technology transfer system

Figure 7 (see Appendix) shows the directions of intra-firm technology transfer system development for machine-building companies in Poltava region. The given study indicates a rather low level of intellectual and innovation activities at the enterprises. PJSC "Kremenchug Plant of Road Machines" and PJSC "Kryukov Railway Car Building Works" have a number of internal problems in recent years, exacerbated by unfavorable external environment.

These enterprises have a "cryogenic" period in development so, first of all, they are recommended to focus on the financial policy and the readiness of production and technical facilities to innovate and conduct researches. Furthermore, companies are to ensure the implementation of preparatory actions, in particular, to renovate the technical facilities and optimize the allocation of net profit to extend internal financial resources.

PJSC "Kremenchug Wheel Plant" and PJSC "AutoKrAZ" are given some other recommendations as their direction of intra-firm technology transfer system development can be characterized as anti-crisis program. Technology transfer system development is mainly complicated by the influence of external environment requiring anti-crisis steps being taken, in particular, by optimizing the financial policy. To lessen (at least partially) the negative impact of the environment these enterprises, in our opinion, a number of steps towards a financial recovery, net income allocation optimization, increasing scientific and technical potential, as well as innovative potential of the personnel must be introduced.

Generally, intra-firm technology transfer of the machine-building enterprises in Ukraine requires implementing the recommendations concerning the creation of appropriate financial and economic conditions and intrapreneurship as effective form of technology implementation.

CONCLUSION

Thus, improving the intra-firm technology transfer is a prerequisite for the successful implementation of innovative development in Ukraine. Development, transfer and commercialization of intellectual and innovative technologies are complicated by the influence of a number of internal and external destabilizing factors, which nature and impact are to be considered to provide a high level of adaptability and flexibility in technology transfer system at the enterprise. This article has provided the matrix approach that allows determining the overall development of intra-firm technology transfer, given the internal capacity to innovate and the favourable conditions at meso- and macro-levels.

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APPENDIX

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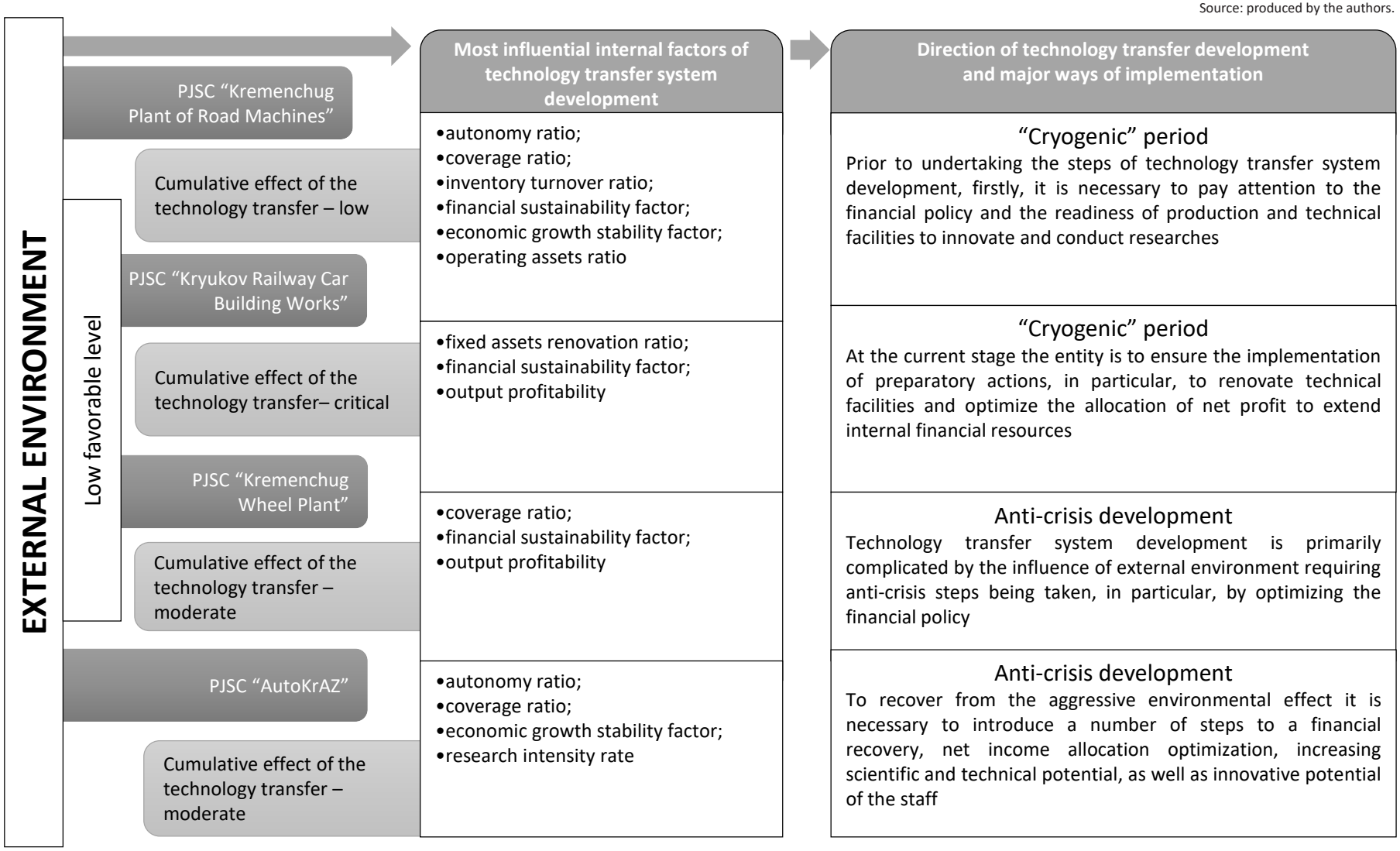

Figure 7. Defining the direction of intra-firm technology transfer system development at PJSC "Kremenchug Plant of Road Machines", PJSC "Kryukov Railway Car Building Works", PJSC "Kremenchug Wheel Plant", PJSC "AutoKrAZ"