ASSESSMENT OF THE IMPACT OF INNOVATIONS ON LABOR PRODUCTIVITY IN DOMESTIC ENTERPRISES

T. Kostenko

Taras Shevchenko National University of Kyiv, 60, Volodymyrska Str., Kyiv 01601 Ukraine
tania-kostenko@ukr.net

Abstract: The paper analyzes results of the innovative activity of industrial enterprises, using surveys of innovative activity in the Ukrainian economy. The study estimates the impact of innovation on labor productivity on the basis of Crepon, Duguet, Mairesse methodology (CDM model). An econometric model is suggested to determine the depending of labor productivity on the research and development, the number of developed new products and new processes implemented in domestic enterprises during the period of 2000-2012. The paper confirms that innovation has a positive impact on labor productivity for Ukrainian enterprises. The purpose of the article is to evaluate the quantitative impact of innovation on labor productivity on the basis of econometric modeling in domestic enterprises.

Keywords: labor productivity, domestic enterprise, impact of innovations, innovative activity, Ukrainian economy, innovations in Ukraine.

Introduction

The current strategy of economic development of Ukraine is aimed at economic restructuring and establishing international economic partnerships. It urgently requires finding some new and improving the existing ways to increase labor productivity. High level of labor productivity is a main prerequisite for the effective functioning of the enterprises in market conditions as well as a major factor of competitiveness and, consequently, a foundation for the improvement of life quality.

In order to achieve sustainable development and to succeed in the competitive market condition enterprises need to increase productivity. Moreover, it is necessary for them to reject the resource-oriented economy in favor of the innovation-driven one.

In an increasingly competitive environment the enterprises, whose flexibility is based on ability to introduce innovations and to adapt to current requirements in shortest terms, are occupying leading market positions, so the importance of the innovative activities is greatly emphasized by the current economic conditions.

While the Ukrainian economists tend to ignore the importance of modeling of the effect of innovations on labor productivity, their foreign colleagues are studying the interrelationship and mutual influence of these factors for many years. Among the researchers concentrating on that topic the following ones are worthy to be mentioned: Loof, H.A. Heshmati, R. Asplund, S.-O. Nåås; Griffith, R., E. Huergo, J. Mairesse, B. Peters; BenaventeJ.; Masso, J., P. Vahter; Crepon, B., E. Duguet; S. Robin; M. Polder, G. VanLeeuwen, P. Mohnen, W. Raymond, O. Grishnova and others.

Despite the empirical studies are abundant, the assessment of the influence of the innovations (both product- and process-wise) is relatively vague, especially in quantitative terms.

Method

The most wide-spread methodic of studying of influence of innovations on labor productivity that the majority of the foreign studies are based upon is a CDM-model developed by Crépon, Duguet and Mairesse (Crepon et al., 1998). In bare outlines the CDM-model is built as a three-stage econometric model which establishes the relationship between labor productivity and innovations and includes a system of three equations: the equations of the innovation input and output and the equation of productivity which are being modeled in sequential order.

Jacques Mairesse and Stéphane Robin have proposed a slightly modified model which includes five equations (Mairesse and Robin, 2010). The first couple of them models the decision making processes dealing
with the expenditure and activity of research and development. The third and fourth equations estimate the amount of knowledge produced as a function of the product- and process-based innovations. The fifth (and the last) equation establishes the influence of both types of innovations onto labor productivity which is defined as a ratio of the GDP to the number of employees. It can be noted mathematically as follows:

\[
\begin{align*}
    \eta_i &= 1(x_{i1}\beta_1 + u_{i1} > 0) \\
    \ln\text{prod}_i &= x_{i2}\beta_2 + u_{i2} \\
    \prod_{k=1}^{5} \eta_i &= 1(a_1\ln\text{rd}_i + x_{i3}\beta_3 + u_{i3} > 0) \\
    \ln\text{proc}_i &= 1(a_2\ln\text{rd}_i + x_{i4}\beta_4 + u_{i4} > 0) \\
    \ln\text{LP}_i &= \delta_1\text{prod}_i + \gamma_1\text{proc}_i + x_{i5}\beta_5 + u_{i5},
\end{align*}
\]

where \( x_{ik} \) (\( k = 1, \ldots, 5 \)) is a vector of independent variables; \( u_{i1} \) is a random value; and \( \beta_k \) is a vector of parameters to be assessed.

The first equation in this system reflects the entrepreneurial decision concerning carrying out the research and development on an ongoing basis. If companies are reporting their research and development activity then \( \eta_i = 1 \); otherwise \( \eta_i = 0 \). The second line describes the company's efforts dedicated to research and development in form of a linear equation between the logarithm of research and development activity (defined as the amount of the research and development investments per employee) and the potential determinants \( x_{i2} \).

The third (the fourth) equation models the company’s possibility to carry out product-based (process-based) innovations during the report period. This couple of equations are expressed by a probit-model which includes endogenous regressor (\( \ln\text{rd} \) is a logarithm of the research and development activity, which in turn is a dependent variable in the second equation of the system (1)) and several exogenous regressors represented by the controlled variables from \( x_{i3} \) and \( x_{i4} \) correspondingly. In literature these two equations are commonly referred to as a knowledge production function.

The fifth equation models logarithm of labor efficiency as a function of product- and process-based innovations and controlled variables.

Thus, the purpose of the CDM model in its essence is to reflect the impact of the innovation expenditures on the results of innovative activity and the impact of the latter on labor efficiency.

Results

To assess the impact of the innovations on labor efficiency in Ukraine using methodology of Crepon, Duguet and Mairesse, let us take into account the innovation activity surveys in the Ukrainian economy during the periods of 2006-2008 and 2008-2010 (obtained using the internationally accepted methodology), the level and dynamics of labor productivity (derived from the purchasing power parity) and build an econometric model which describes the relationship between the innovation activity and labor productivity.

Consider the following source data for the model.

1. The first equation of system (1) reflects the decision of a company to implement some innovations. The dependent variables can include: the amount of investments in internal and external scientific research and development (R&D), acquisition of machinery, equipment and software, acquisition of patents and know-how and other knowledge from third parties; organization of basic training for personnel to carry out the innovation activities in order to develop novel or significantly improved products or processes and to introduce novel or significantly improved products or processes to the market (Fig. 1).

![Fig.1 Percentage of the Ukrainian industrial enterprises engaged in innovative activities in the periods of 2006-2008 and 2008-2010](image)

Source: composed by the author
One of the key directions of innovative activities of the Ukrainian enterprises during the study period is primarily the acquisition of machinery, equipment and software to produce novel or significantly improved products and services. This kind of innovative activities has been reported by 72.2% of the industrial enterprises for the period of 2006-2008 and by 72% – for the period of 2008-2010. Quite a significant number of companies have been conducting training and education programs aimed at development and implementation of novel or significantly improved products and processes (30.4% of industrial enterprises in the period of 2006-2008 and 26.2% – in 2008-2010). The period of 2008-2010 has seen a declining share of the industrial enterprises conducting research and development on their own (24% vs. 29.9% in 2006-2008). Nonetheless this index exceeds the percentage of the enterprises obtaining the external knowledge and results of research and development from some other companies and organizations (11.3% for the period 2008-2010).

The independent variables in the first equation are: the size of the company, which is defined as the natural logarithm of the number of employees; three dummy variables characterizing the market orientation of the companies (the domestic market, the EU market, some other markets; Fig. 2); four dummy variables characterizing the set of factors hindering the implementation of innovations (Table 1); two dummy variables, reflecting the implementation of organizational and marketing innovations.

![Fig.2 The percentage of the Ukrainian enterprises engaged in collaborative innovative activities with partners from different parts of the world](source: composed by the author)

Total amount of the domestic industrial enterprises engaged in collaborative innovation activities with some other companies and organizations was 29.3% in the period of 2006-2008 and 20.5% in the period of 2008-2010. During the period of 2008-2010 20% of domestic enterprises were choosing domestic enterprises and organizations as their main partners in innovation activities which is 7.2% less than in 2006-2008; in 8.3% of cases the main partners of choice were European companies (vs. 10 4% in the period of 2006-2008); in 1% of cases – companies from the United States (vs. 1.8% in the period of 2006-2008); and in 1.4 % of cases the main partners in innovation activities were companies from China and India, which is less than in 2006-2008 (by 2.2%).

Table 1

<table>
<thead>
<tr>
<th>Causes of innovation</th>
<th>Innovative enterprises</th>
<th>Non-innovative enterprises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monetary factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of funds</td>
<td>7,8</td>
<td>16,3</td>
</tr>
<tr>
<td>Insufficient level of external financing</td>
<td>4,6</td>
<td>8,7</td>
</tr>
<tr>
<td>Excessive expensiveness of the innovation activities</td>
<td>6,2</td>
<td>12,0</td>
</tr>
<tr>
<td>Information-related factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shortage of competent personnel</td>
<td>1,5</td>
<td>3,4</td>
</tr>
<tr>
<td>Lack of information about the technologies</td>
<td>1,0</td>
<td>2,1</td>
</tr>
<tr>
<td>Lack of information about the market</td>
<td>0,8</td>
<td>1,9</td>
</tr>
<tr>
<td>Difficulties in finding partners in innovation activities</td>
<td>2,4</td>
<td>5,3</td>
</tr>
<tr>
<td>Market-related factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market monopolization</td>
<td>3,9</td>
<td>7,1</td>
</tr>
<tr>
<td>Insufficiency of demand for certain innovative products or services</td>
<td>1,9</td>
<td>4,2</td>
</tr>
<tr>
<td>Causes of innovation</td>
<td>The opportunities for innovations have been exhausted in previous report period</td>
<td>1,1</td>
</tr>
</tbody>
</table>
Numerous factors were hindering the innovations. In most cases the innovation activities require significant investments into technical equipment and salaries attractive for the highly qualified personnel. These costs are quite high and do not guarantee a quick payback. So the biggest obstacle for the enterprises to implement innovations is the monetary factor.

A lot of markets are fiercely competitive, some of them are prone to be overstocked and permanent generation of new ideas for production of novel goods and services is not always an easy task. These obstacles form a group of market factors. The factors related to collaboration and information exchange issues as well as with the highly qualified personnel availability form an information factors group.

2. The second equation (innovation input) of system (1) contains a dependent variable describing a total amount of finances consumed by the innovative activities of a company (Fig. 3).

![Fig.3 The amount of expenses spent by the Ukrainian industrial enterprises for innovations during the period of 2005-2011, UAH million](image)

*Source: composed by the author*

Amount of expenses for the innovation activities of the industrial enterprises grows during the period of 2005-2008, but in 2009 it decreases by more than 30%. In comparison to 2010 the number of the enterprises investing in innovation activities has grown by more than 20%. In 2011 the amount of financing of the innovation activities has reached 14.3 billion UAH (in 2010 – 8 billion UAH).

The independent variables of the second equation are: the dummy variables reflecting the percentage of the enterprises whose innovative activities were financially supported by the state and four dummy variables describing the most important source of information used for the innovation activities (Table 2).

### Table 2

<table>
<thead>
<tr>
<th>Internal</th>
<th>Sources belonging to the organization or a group of the organizations</th>
<th>2006-2008</th>
<th>2008-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market sources</td>
<td>Providers of the equipment, consumables, components or software</td>
<td>18,8%</td>
<td>19,9%</td>
</tr>
<tr>
<td></td>
<td>Clients or buyers</td>
<td>18,6%</td>
<td>19,2%</td>
</tr>
<tr>
<td></td>
<td>Competing and other organizations from the same sector</td>
<td>9,0%</td>
<td>9,6%</td>
</tr>
<tr>
<td></td>
<td>Advisors, commercial laboratories or private R&amp;D establishments</td>
<td>4,8%</td>
<td>4,2%</td>
</tr>
<tr>
<td>Institution sources</td>
<td>Universities and other academic institutions</td>
<td>2,2%</td>
<td>1,8%</td>
</tr>
<tr>
<td></td>
<td>State and private R&amp;D establishments</td>
<td>4,7%</td>
<td>4,6%</td>
</tr>
<tr>
<td>Other sources</td>
<td>Conferences, trade shows, exhibitions</td>
<td>17,7%</td>
<td>14,5%</td>
</tr>
<tr>
<td></td>
<td>Scientific magazines</td>
<td>11,8%</td>
<td>8,7%</td>
</tr>
<tr>
<td></td>
<td>Professional and industrial associations</td>
<td>3,5%</td>
<td>3,3%</td>
</tr>
</tbody>
</table>

*Source: composed by the author*

The consumers and the providers of the equipment, consumables, components and software supply the companies engaged in innovation activities with very important information. But the collaboration channels with scientific and especially with educational establishments look rather weak and underused.
The share of the enterprises whose innovation activities are financially supported by the state during the period of 2008-2010 has grown by 1.6% in comparison to the period of 2006-2008 due to the growing amount of financing from the central, regional and local state authorities.

1. The third (fourth) equation of the system (1) (innovation output) contains a dependable variable computed as a natural logarithm of the share of the novel products and services in total volume sales (Fig. 4).

Fig. 4 The amount of innovative products and services and its share in total volume sales in Ukraine during the period of 2005-2011

Source: composed by the author

In the year of 2011 the volume of the innovative products sold by 1043 enterprises has amounted to 42.4 billion UAH (vs. 964 and 33.7 billion UAH respectively in 2010) or 3.8% of the industrial products.

The independent variables of the third equation of the model are: the size of a company; the volume the financing of the innovation activities (Fig. 3), which is a dependent variables in the second equation; four dummy variables describing the most important source of information used for the innovation activities (Table 2); two dummy variables reflecting the activity of introduction of organizational and marketing innovations; and dummy variables reflecting the share of the enterprises whose innovation activity was financially supported by the state.

3. The dependent variable of the fifth equation of system (1) is a natural logarithm of labor productivity computed as a ratio of the GDP to the number of employees (Fig. 5).

Fig. 5 Labor efficiency in Ukraine and the rate of its growth in the period of 1999-2012

Source: composed by the author

During the period investigated (1999-2012) labor efficiency has been steadily growing. The only turning point was in the year of 2009, when the sales volume of innovation activity products, the amount of investment in innovations and other indicators of innovation activity went down for numerous enterprises.

The independent variables of the fourth equation of the model are: the natural logarithm of the share of the novel products and services in total sales volume (Fig. 4) which is a dependent variable in the equation 3 (4); two dummy variables reflecting the pace of the introduction of innovations into production processes and mastering the production of innovative products (Fig. 6); and four dummy variables describing the factors hindering the introduction of the innovations (monetary and market ones etc; Table 1).

In the year of 2011 731 enterprises have introduced 3238 items of different products, which exceeded the data of the previous year by 34.5%. In particular, the novel machines, pieces of equipment, instruments and apparatus were amounted to 897 items. 900 items were considered to be novel for the market exclusively which corresponds to 27.8% of the total amount. 677 enterprises have reported the introduction of novel processes. 605 enterprises have introduced novel methods of processing or production and 517 of them were
low-waste and resource-saving ones. 83 enterprises have introduced novel or improved logistics, delivery or distribution processes; 140 – novel or improved methods of support of the production processes including the material support as well as the purchasing, accounting and financial settlement systems.

Let us use Eviews 4.0 computer program to assess the influence of the research and development investment (RD) and quantity of the novel products introduced into production (PROD) on labor efficiency in the Ukrainian enterprises during the 2000-2012 period. The non-linear model proved to be the most adequate one:

```
DependentVariable: LOG(LP)
Method: LeastSquares
Date: 11/16/13   Time: 11:57
Sample: 2000 2012
Includedobservations: 13

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOG(PROC)</td>
<td>0.123712</td>
<td>0.032866</td>
<td>3.764162</td>
<td>0.0055</td>
</tr>
<tr>
<td>LOG(PROD)</td>
<td>0.051231</td>
<td>0.022523</td>
<td>2.274558</td>
<td>0.0525</td>
</tr>
<tr>
<td>LOG(RD)</td>
<td>0.120693</td>
<td>0.029422</td>
<td>4.102205</td>
<td>0.0034</td>
</tr>
<tr>
<td>LOG(VALUEADD)</td>
<td>1.045145</td>
<td>0.109813</td>
<td>9.517528</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>-5.574359</td>
<td>1.401460</td>
<td>-3.977538</td>
<td>0.0041</td>
</tr>
</tbody>
</table>

R-squared 0.994290
Adjusted R-squared 0.991435
S.D. dependent var 0.250442
S.E. of regression 0.023178
Akaike info criterion -4.407542
Sum squared resid 0.004298
Schwarz criterion -4.190254
Log likelihood 33.64902
F-statistic 348.2680
Durbin-Watson stat 2.415422
Prob(F-statistic) 0.000000
```

As is obvious, all the variables of the model (except the ones related to product innovations) are significant when the significance level is 5% or 1%, as Prob<0.01. The model is adequate because the determination quotient (R-squared) and the corrected determination quotient (AdjustedR-squared) > 0.75 and are respectively equal to 0.994 and 0.991, while Prob(F-statistic) > 0.05 and is equal to 0.01. Therefore the result of the modeling is acceptable.

The model has the following mathematical interpretation:

\[ \text{LOG(LPGDPT)} = 0.1237124094 \times \text{LOG(PROC)} + 0.05123064799 \times \text{LOG(PROD)} + 0.1206931947 \times \text{LOG(RD)} + 1.045144644 \times \text{LOG(VALUEADD)} - 5.574358893. \]

Discussion

Thus the performed investigation shows a positive influence of the innovations on labor efficiency of the Ukrainian enterprises. The impacts of the logarithms of the activity of the introduction the novel processes and products as well as the amount of research and development investments onto the logarithm of labor efficiency are equal to 12.44%, 5.12% and 12.07% respectively. The results show that only the process innovations (unlike the product ones) are significant for labor efficiency. This can indicate either that the companies have failed to convert the product innovations into a tangible labor efficiency increase or that the time lag of the product innovation influence exceeds the observation time interval.
Demographic, social and political aspects of the Ukraine reality give grounds to perceive the labor efficiency improvement as one of the most important answers to the wide set of challenges. The significance of the innovations for labor efficiency, which has been shown above, proves the expediency of creating an environment capable of stimulation the entrepreneurial innovation activity for the purpose of economic growth, living standards improvement and social development.

References