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Technological progress spillover effect in Lithuanian manufacturing industry

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Abstract

Research background: Various methods for technological progress assessment and evaluation exist in the context of economic development. Each of the methods possesses distinct advantages and disadvantages in analysis of technological progress fluctuations. For most neoclassical growth theories, technological progress measures are included as exogenous variables, thus excluding evaluation of factors influencing technological progress variation throughout time.
Purpose of the article: The aim of this article is to offer improvements on classical technological progress evaluation methodologies for manufacturing industries, separating effect of intersectoral technological progress spillover effect from internal factors influencing technological progress growth and perform analysis in the case of Lithuanian manufacturing industry.
Methods: Earlier research papers used linear time series regression and vector autoregression methods to assess technological progress values and define equations explaining effect of different manufacturing level indicators on technological progress measure growth. This research paper uses results of previously mentioned methods and performs simulation analysis applying agent-based modelling framework.
Findings & value added: The conducted vector autoregression analysis has showed that two variables which influence technological progress most significantly are labor productivity measure and gross profit value. Sensitivity analysis emphasizes that effect of these two variables on

technological progress growth is substantially different. Increase in gross profit value affects technological progress growth for wider range of sectors from Lithuanian manufacturing industry (15 out of 18 analyzed sectors' technological progress measure values are affected by changes in gross profit, while changes in labor productivity influence technological progress values in the case of 9 sectors). Rising gross profit values also produce intersectoral technological progress spillover effect more significantly, while growth in labor productivity measure has stronger effect on technological progress fluctuations for sectors which are able to exploit this effect. Presented research suggests improved methodology for intersectoral technological progress spillover effect assessment in the context of manufacturing industries.

Introduction

Effect of technological progress on economic growth has been studied by various researchers throughout time. Many research papers are dedicated to emphasize the importance of technological development for sustainable long term economic growth. According to Galor and Tsiddon (1997), interplay between technological progress and two components, parental specific human capital and individual ability, influences evolution of wage inequality, intergenerational earnings mobility, pace of economic growth. Several theoretical models suggest that markets consisting of companies specializing in technologically progressive activities will enjoy higher rates of productivity growth compared to companies operating in markets, which employ less technologically advanced methods (Fagerberg, 2000). The research conducted by Greenwood and Seshadri (2004) even indicates that technological progress induced dynamic fluctuations of fertility rates and affected demographic transitions of different economies.

There exist different growth theories trying to explain technological progress effect on economic development throughout time. Two main ones are neoclassical growth theory and endogenous growth theory (Sredojevic, *et al.*, 2016; Solow, 1999; Aghion & Howitt, 2009; Englmann, 1994). According to neoclassical growth models without technological changes, in a state of stable equilibrium, long-term growth in production per capita cannot exist. Endogenous growth models try to extend the neoclassical growth theory by eliminating the premise of diminishing returns on production factors. Endogenous growth theory removes the implication of convergence and achievement of steady-state growth equilibrium. Both theories have their own shortcomings. In neoclassical growth models many variables are assumed to be exogenous, while in reality they are evolving in a continuous dynamic process (Van den Berg, 2012). Most importantly, the rate of change in technological progress measures are regarded as given. Endogenous growth theory models try to eliminate exogeneity problem of technological progress variables, although still has its own limitations.

Popular criticisms for endogenous growth models consist of uncertainty in modelling the individual decision making, restriction in the analysis of steady state equilibria (Alcouffe & Kuhn, 2004). Despite the differences, both theories agree on the importance of technological progress in evolution of economic development.

According to the data provided by International Trade Center, the value of internationally traded goods between 2001 and 2019 grew at average by the annual rate of 5.5 percent. With increasing importance of globalization and international business relationships between countries, technological spillover effect becomes more significant in dynamic fluctuations of technological progress. Technological spillover effect refers to the activity in one region which affects the values of technological progress and amount of economic growth in neighboring regions (Lin *et al.*, 2017). The extent of technological spillover effect can be influenced by different factors like foreign direct investment, levels of international trade, infrastructure development and public capital investment. As many empirical studies support the presence of technological spillover, international relationships between countries can create two distinct types of spillover effects (Bloom *et al.*, 2013). Technological (or knowledge) spillover effect can increase productivity of companies operating in similar technology areas. Product market rivalry effect has a negative impact due to increased competitiveness in the market. Various factors influence whether technological spillover or product market rivalry effect is stronger for each particular company operating in analyzed market.

As globalization and technological spillover effect have an increasing impact on technological development assessment in different markets and current growth theories possess limitations, explaining technological progress effect on economic growth, modernized methods for technological progress evaluation are required. Majority of researchers, while analyzing technological progress spillover effect, either concentrate on large markets, like China (Hu *et al.*, 2018; Yang *et al.*, 2017), or analyze technological progress spillover effect in the context of international relations between countries, through foreign direct investments (Iwasaki & Tokunaga, 2016; Naveed & Ahmad, 2016). Thus, intersectoral technological progress spillover effect lacks attention, especially in the area of Central/Eastern Europe. This article is dedicated to suggesting improvements for technological progress development assessment in case of manufacturing industries, distinguishing intersectoral technological progress spillover effect from effects of other internal sector level parameters and verifying constructed methodology practically. The goal of this research is to evaluate intersectoral technological progress spillover effect in the case of Lithuanian manufacturing industry using agent-based modelling. The Lithuanian manufacturing industry was chosen for analysis because the presented paper is a part of broader research collection, where technological progress evaluation model is constructed in case of Lithuanian manufacturing industry.

This article consists of introduction, literature review, research methodology, results, discussion and conclusions. Literature review analyses theoretical technological progress and spillover effect evaluation aspects, research methodology is used to describe the model applied for intersectoral technological progress spillover effect assessment, the results section presents the results of conducted sensitivity analysis, the discussion section compares results with other relevant research papers and the conclusions section gives a summary of the findings obtained from the presented research.

Literature review

Solow constructed a neoclassical growth theory in which he built a framework for technological progress measure assessment. The basis for the growth theory is production function, presented in the Equation 1 (Hulten, 2001):

$$Q_t = A_t F(K_t, L_t) \tag{1}$$

In the given equation parameter A_t represents the shift in the production function with fixed amounts of labor and capital employed in the production function, also known as Total Factor Productivity (TFP). Transformation of Equation 2 in the form of total logarithmic differential is presented as:

$$\frac{\dot{Q}_t}{Q_t} = \frac{\partial Q}{\partial K}\frac{K_t}{Q_t}\frac{\dot{K}_t}{K_t} + \frac{\partial Q}{\partial L}\frac{L_t}{Q_t}\frac{\dot{L}_t}{L_t} + \frac{\dot{A}_t}{A_t} \tag{2}$$

According to Equation 2, growth of produced output consists of growth rates of capital and labor, weighted by their respective output elasticities, and growth rate of TFP measure. Output elasticity of capital and output elasticity of labor can be substituted by their corresponding marginal products. This technological progress effect on economic growth can be described as:

$$R_t = \frac{\dot{Q}_t}{Q_t} - s_t^K \frac{\dot{K}_t}{K_t} - s_t^L \frac{\dot{L}_t}{L_t} = \frac{\dot{A}_t}{A_t} \tag{3}$$

In Equation 3, parameter R_t represents Solow residual measure. This measure indicates the residual growth of output not explained by the inputs used in production function. The problem with the introduced measure is that Solow residual includes not only effects of technical and organizational innovation, but also measurement error, omitted variables bias, aggregation bias and model misspecification terms. This drawback can be at least partially eliminated by including additional independent variables into equation of production function and analyzing TFP measure as endogenous parameter. Fluctuations in TFP growth are caused by endogenous innovation decisions, thus having significant implications on business cycles (Comin, 2010). Low-presence non-technical shocks might generate pro-cyclical fluctuations in the market value of innovations. While agents try to arbitrage these innovation opportunities, generating a pro-cyclical rate of innovation development thus introducing changes in TFP growth rate.

Technological spillover effect could help to endogenize analysis and interpretation of TFP parameter in economic growth models. Technological (or productivity) spillover can be explained through R&D expenses, exports and foreign direct investment (Wei & Liu, 2006). R&D expenses not only affect the productivity of the firm which invests into R&D directly, but may also produce spillover effects. According to Zhao *et al.* (2019), an increase in R&D expenses can lead to an increase in technology absorption capacity transferred by spillover effect from external markets. A complimentary effect between foreign direct investment and R&D expenses was also identified (Wang & Wong, 2016). This indicates that companies which invest into productivity growth take advantage of stronger benefit created by knowledge spillover effect from interaction with companies which possess higher levels of technological development.

The incentive to invest into R&D, according to the endogenous growth theory, is created by the possibility of gaining monopolistic profits earned in case of a ground-breaking technological innovation. This is represented by the following equation (Chu *et al.*, 2017):

$$\Pi_t(\omega, j_\omega) = [\lambda_t(\omega) - 1]\, y_t(\omega, j_\omega) = \left[\frac{\lambda_t(\omega) - 1}{\lambda_t(\omega)}\right](1 - \theta)Y_t \qquad (4)$$

In Equation 4, the parameter $y_t(\omega, j_\omega)$ represents production function of intermediate goods, while $\lambda_t(\omega)$ is the equilibrium market price. Each industry is dominated by the quality leader, which has the highest level of technological productivity, until another market player creates innovation, which supplies new highest quality product. Monopolistic profit $\Pi_t(\omega, j_\omega)$ is the incentive for innovation. When a market is competitive, then monopolistic profit is shared by many players of the market. Parameter ω indicates the continuum of different industries, thus when a new innovation is created, through spillover effect it is shared between different markets.

There are different types of technological spillover effects: intrasectoral and intersectoral. In this research we are concerned with intersectoral technological spillover effect. Various research papers have analyzed the presence of intersectoral technological spillover effect. According to Dieppe and Mutl (2013), intersectoral technological spillover exists in 10 different OECD countries and 12 sectors analyzed. They have concluded that in a short term intersectoral technological spillover effect, created due to investment in R&D, has a negative effect on the TFP value, but the long-term effect is positive. Mitze *et al.* (2016) also analyzed intersectoral and international spillover effect for 13 different OECD countries and concluded that in both cases an increase in R&D expenses has a significant effect on sectoral productivity growth. This research has also concluded that in long-term intersectoral spillover effect has a significant presence, while in short-terms the results concerning intersectoral spillover effect are inconclusive.

Besides foreign direct investment, R&D expenses and the ability to generate profits which can be reinvested into further growth and technological progress, labor productivity is another important aspect of long-term economic development. Malmquist output-oriented productivity index was introduced to help describe relationship between productivity and technological progress in the context of economic growth. The index can be depicted as the following (Worthington & Lee, 2008):

$$M_O^{t+1} = (y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{D_O^t(y_{t+1}, x_{t+1})}{D_O^t(y_t, x_t)} * \frac{D_O^{t+1}(y_{t+1}, x_{t+1})}{D_O^{t+1}(y_t, x_t)}\right]^{1/2} \quad (5)$$

In Equation 5, parameter O indicates the output orientation of the index, while M is the productivity of most recent production point with the input variable x_{t+1} and output variable y_{t+1}, compared to the input and output parameters of previous production point (y_t, x_t). Malmquist index helps to distinguish whether economic growth is achieved due to increased labor productivity indicated by upward shift of production function (also indicating a growing value of TFP) or as a result of increased technological efficiency. A research paper by Crespi and Zuniga (2012) conclude that there is a strong positive relationship between innovation input and output, and innovation output and productivity. The firms that invest in knowledge are more capable of introducing technological advances which result in higher labor productivity. Research also suggests that companies which invest in knowledge are the ones that are more productive.

In order to assess the influence of different factors on technological progress development and evaluate intersectoral spillover effect between sectors in the manufacturing industry, two main methods are implemented: vector autoregression model and agent-based modelling. Vector autoregression model is a good way to trace out time path of how changes (or shocks) in particular modelled variable can induce fluctuations of other analyzed variables (Shan, 2005). Thus dynamic relationship between economic variables can be explored, which can be easily adopted to technological progress spillover effect evaluation. In its basic form vector autoregression model can be represented by the given equation (Awokuse, 2006):

$$X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i X_{t-k} + \varepsilon_t \tag{6}$$

In Equation 6, parameter X_t represents vector of historical data while X_{t-k} indicates n*1 column vector of lagged values for the analyzed variable, while Γ is the coefficient matrix. Parameters in more advanced vector autoregression models can be separated into endogenous and exogenous, as presented in equation 7 (Zhou & Luo, 2018):

$$y_t = \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + H x_t + \varepsilon_t,\ t = 1,2,\ldots,T \tag{7}$$

In the given equation parameter y_t represents the vector of endogenous variables, x_t indicates the vector of exogenous parameters and ε_t is the error term. The endogenous parameters are included into vector autoregression models with their lagged values. This helps to analyze dynamic changes of the given variables when other parameters in the model alter. The exogenous variables are included in vector autoregression models in their current time period t. They are designed to explain the structural changes in the model which cannot be explained by endogenous variables.

All in all, vector autoregression models have an edge over other stochastic process models, mainly due to two reasons. Firstly, a large number of explanatory variables can be included into the model, thus helping to explain fairly complex relationships between parameters. This requires an assumption that data is available for fairly large amount of timeframe and enough degrees of freedom is available in the model. Secondly, when the exogenous variables are excluded from the model, forecasting models built using vector autoregression framework are comparatively easy to interpret and fairly accurate compared to larger and clunkier systems of equations.

After vector autoregression models help to define the relationships between variables, agent-based modelling helps to perform simulations and sensitivity analysis which show how changes in different parameters influence technological progress growth in the context of technological spillover effect. Advantage of agent-based models over other alternatives in performing simulations or sensitivity analysis is the fact that given framework allows to simulate individual actions of diverse agents while measuring the results of observed system over time (Crooks & Heppenstall, 2012). The more standard approaches usually represent complex systems in a more static way with largely homogenous entities modelled with identical characteristics. According to Janssen (2005), within the field of evolutionary economics agent-based models are used to simulate innovation, diffusion and learning of firms and organizations. Conventional economic models assume selfish rational behavior of market participants, which is not always the case. Agent-based modelling helps to provide a good description of behavior for various decision-making economic situations (economic valuation and collective action, motivation, principles of fairness and preferences).

No research which analyses intersectoral technological progress spillover effect in the case of Lithuanian or other Central/Eastern Europe countries was found. Lafi (2018) carried out research analyzing horizontal and backward technological progress spillover, although produced output, not total factor productivity parameter, was used to the capture spillover effect. Lopez-Pueyo (2008) analyze both intersectoral and intra-sectoral technological progress spillover effect of various developed countries, although in the research the total factor productivity parameter is expressed strictly through R&D expenditure and the effect of other variables on technological progress measure is not considered in constructed model. Apa *et al.* (2018) also performs a detailed analysis of technological progress measure change on various European regions, although no effort was made to directly include technological progress spillover effect into analysis of the results.

Method

Research was carried out for sectors operating in the Lithuanian manufacturing industry. All data was gathered from the Lithuanian department of statistics. The time period for the conducted research is 2000–2018. Table 1 presents all sectors used in the analysis with their respective codes. When describing the results of the conducted research, identification codes will be used to define these sectors.

Initially, technological progress values were estimated on the basis of Solow's neoclassical growth theory, represented by formula:

$$Y_t = AK_t^{\alpha} L_t^{\beta} \ ; \ \alpha, \beta \ \geq 0 \tag{8}$$

In Equation 8, the variable Y_t represents gross domestic product of the analyzed sector, while K_t indicates the amount of physical capital employed in the production process. The only unknown parameter needed to assess the TFP value is α, representing output elasticity of capital measure (as parameter β is considered to be equal to $1 - \alpha$). Output elasticity of capital value can be estimated with the help of time series regression function:

$$\ln(Y_t) = \beta_1 + \beta_2 * \ln(K_t) + \beta_3 * \ln(EN_t) + \beta_4 * \ln(CASH_t) + \beta_5 * \ln(ETD_t) + \beta_6 * \ln(EXP_t) + \beta_7 * \ln(INV_t) + \beta_8 * T + \varepsilon_t \tag{9}$$

In Equation 9, the output elasticity of capital is represented by parameter β_2. Besides variables Y_t and K_t, which are present in production function of Solow's neoclassical growth model, additional independent variables are included into the model to solve endogeneity problem of time series regression. These include sector's cash ration ($CASH_t$), leverage ratio (ETD_t), ratio of export turnover to total turnover (EXP_t) and reinvestment ratio (INV_t). Time trend variable T is also included into the model to account for trends witnessed in the demand side of the market as time series regression, defined in equation 9, represents variables which only explain the supply side effects on economic development. After output elasticity of capital estimation, the TFP measure can be evaluated with the help of given equation:

$$A_{i,t} = \frac{Y_{i,t}}{K_{i,t}^{\alpha_{i,t}} * L_{i,t}^{(1-\alpha)_{i,t}}} \tag{10}$$

After TFP values are estimated, vector autoregression model can be built, where the system of functions for sectors operating in Lithuanian manufacturing industry can be represented as:

$$A_{i,t} = \alpha_i + \sum_{k=1}^{3} \beta_{i,t-k} A_{i,t-k} + \sum_{k=1}^{3} \gamma_{j,t-k} A_{j,t-k} + \sum_{k=1}^{3} \delta_{i,t-k} INV_{i,t-k} + \theta_{i,t} LP_{i,t} + \rho_{i,t} CR_{i,t} + \varphi_{i,t} GP_{i,t} + \varepsilon_{i,t} \tag{11}$$

Variables included into VAR model can be distinguished into two parts: endogenous and exogenous. Endogenous variables are included into the model with their lagged values. These include technological progress values of analyzed sectors of the Lithuanian manufacturing industry and reinvestment ratios of analyzed sectors. Exogenous variables are included into the model with current time period values. These include labor productivity ratio LP_i, foreign capital structure ratio CR_i and inflation-adjusted gross profit value measure GP_i.

For endogenous variables included into vector autoregression model, a lag value of 3 periods was chosen. This decision was made due to two reasons. Firstly, a research by Verspagen and Loo (1999) suggests that at lag length of three years, intersectoral technological progress spillover effect reaches its' peak level. Thus, including TFP values with a lag length of 3 into VAR model should be enough to detect the presence of intersectoral technological progress spillover effect. Secondly, data for sectors operating in the Lithuanian manufacturing industry is available for only 19 years. If longer lag value is chosen for given VAR model, a problem due to insufficient level in degrees of freedom can arise.

When functional forms of TFP measures are established, a sensitivity analysis is carried out with the help of agent-based modelling methodology. While performing agent-based modelling simulation, functions obtained from VAR model (Equation 11) are used to determine how changes in various factors influence technological progress measure fluctuations. Combining VAR model functions with simulation constructed on the basis of agent-based modelling methodology allows identification of more complex relationships between analyzed parameters. Agent-based modelling methodology is also suitable for distinguishing which part of technological progress growth is influenced by internal variables of a given sector and which part is induced by intersectoral technological progress spillover effect.

TFP measure estimation and construction of VAR model has already been carried out and the results have been published (Markauskas & Saboniene, 2019; Markauskas & Baliute, 2020). This research paper presents the results of sensitivity analysis performed using agent-based modelling technique, which uses functional forms of technological progress measures obtained from constructed VAR model.

Findings

The previously performed VAR analysis indicated that in the case of 15 out of 18 analyzed sectors operating in the Lithuanian manufacturing industry, gross profit measure had a significant influence on technological progress values, while in the case of 10 out of 18 analyzed sectors labor productivity significantly influenced fluctuations in technological progress changes. For that reason, these two variables were chosen to be used in the sensitivity analysis. Both of presented variable values were increased by 5 percent and

10 percent for all sectors operating in the Lithuanian manufacturing industry. Then, the influence of these changes on technological progress values were estimated, and the effect itself separated into growth due to internal variable fluctuation and growth due to intersectoral technological progress spillover effect.

Firstly, inflation-adjusted gross profit measure was increased by 5 percent for all sectors operating in the Lithuanian manufacturing industry. Annual growth of TFP measures due to these changes are presented in Table 2.

The largest annual TFP measure growth due to 5 percent increase in gross profit is witnessed in the case of leather and leather products sector. Annual technological progress growth of presented sector is 2.6 percent. Out of 18 analyzed sectors, in the case of 4 annual technological progress growth was identified to be 2 percent or larger, in the case of 13 sectors — at least 1 percent. Exclusive characteristic of inflation-adjusted gross profit variable is the fact that each sector operating in the Lithuanian manufacturing industry was affected by intersectoral technological progress spillover effect due to growth of gross profit measure. This is despite the fact that in the case of 3 sectors their internal gross profit measures did not affect technological progress growth and their estimated TFP growth in the performed simulation was fully influenced by technological progress spillover effect. Out of all 18 analyzed sectors 2 manage to absorb technological progress spillover effect in a very efficient manner — printing and reproduction sector and other transportation equipment sector registered 1.2 percent annual TFP measure growth due to intersectoral technological spillover effect.

Figure 1 presents dynamic changes of annual technological progress growth rates (due to increase in gross profit variable) for two fastest growing sectors: leather and leather products and furniture. Although the average annual growth rates for these two sectors are the same, the tendency of change throughout time is very different. In the case of leather and leather products sector, at early stages annual technological progress growth rate was very large, containing 9.9 percent growth rate in 2004. At early stages, close to all of technological progress growth was obtained through internal factors. Despite rapid growth in early years, throughout time annual technological progress growth rate declined, possessing lowest value of 1.5 percent in 2018. Although in earlier years technological progress growth was mainly influenced by internal factors of leather and leather products sector, at the end of the analyzed timeframe the main catalyst of technological progress measure growth was intersectoral technological progress spillover effect. Between 2014 and 2018, the annual technological progress growth rate due to internal factors was 0.2 percent, while technological progress growth due to intersectoral spillover effect was 1.2 percent.

In the case of furniture sector, the trend for annual technological progress growth rate is totally different. In the beginning of analyzed time frame, technological progress grew at a slower pace, recording average 1.2 percent growth rate between 2003 and 2007. After 2007, the annual technological progress growth rate increased, largely influenced by accelerating influence of intersectoral technological progress growth rate. During the interval of 2010-2016, the average annual technological progress growth rate increased by 1.8 percent due to internal factors of analyzed sector operating in the Lithuanian manufacturing industry, while during the same period intersectoral technological progress spillover effect increased technological progress measure at the average pace of 1.3 percent.

The biggest similarity between both analyzed sectors is the dynamic effect of technological progress spillover effect. In both cases, it took time for technological progress spillover effect to take place and after that for a while technological progress growth due to intersectoral spillover effect grew at an incrementing pace until the grow rate reached its' limit and settled down.

Table 3 presents the results of another agent-based modelling sensitivity analysis. In the provided simulation, the annual technological progress growth rate was measured due to an increase in gross profit values for all companies operating in the Lithuanian manufacturing industry by 10 percent. The sectors with the fastest growing technological progress values in the presented simulation are the same as in the sensitivity analysis, where gross profit measures were increased by 5 percent. The largest annual technological progress growth rates were recorded in the case of leather and leather products sector with an average value of 5.3 percent, while the sector with the slowest annual technological progress growth was computer, electronics and optical devices producing sector, with the average growth rate of 0.3 percent.

The strongest intersectoral technological progress spillover effect was witnessed again in the case of leather and leather products sector, where technological progress annual growth rate due to spillover effect was estimated to be 2.57 percent. As in previous simulation, only 3 sectors out of 18 operating in the Lithuanian manufacturing industry analyzed did not benefit from intersectoral technological progress spillover effect.

Table 4 presents the results of sensitivity analysis where labor productivity of all companies operating in the Lithuanian manufacturing industry was increased by 5 percent. In that scenario, only 3 out of 18 analyzed sectors did not register technological progress growth due to the increase in labor productivity. The largest growth was witnessed in the case of computers, electronics and optical devices sector, where annual average technological progress growth rate was recorded to be 4.4 percent. When analyzing the effect of gross profit value on technological progress growth, an increase in gross profit by 5 percent led to estimated average technological progress growth rate of 2 percent or larger in the case of 4 sectors. When analyzing labor productivity, 9 sectors' technological progress measure grew by average annual rate of 2 percent of larger due to increase in labor productivity by 5 percent. Another distinction of labor productivity effect on technological progress growth is the lack of intersectoral technological progress spillover effect. In the case of 9 sectors out of 18 analyzed, no effect of technological progress spillover effect was witnessed.

Lack of technological progress spillover effect presence can be justified by the fact that only two sectors out of 18 analyzed recorded larger than 1 percent growth rate of technological progress measure due to intersectoral technological progress spillover. In the case of leather and leather products sector, the average annual technological progress growth due to spillover effect was 2.6 percent, while in case of printing and reproduction sector the growth rate was 1.2 percent.

Figure 2 presents dynamic changes of annual technological progress growth rates for two largest growing sectors in the provided simulation, where labor productivity was increased for every sector by 5 percent. In the case of computers, electronics and optical devices sector technological progress growth due to increase in labor productivity initially increased at a rising pace: from 2.7 percent in 2003 to 6 percent in 2007. From 2008 up until 2018, technological growth rate slowly declined, ending the analyzed timeframe at 3.8 percent. Computers, electronics and optical devices sector managed to sustain largest annual technological growth rate out of all analyzed sectors operating in the Lithuanian manufacturing industry without any help of intersectoral technological progress spillover effect.

In the case of textile sector, the annual technological progress growth rate also started increasing at a rising pace, and from the value of 2.1 percent in 2003, it reached 4.7 percent in 2009. Later, the growth rate slowed down and finished the analyzed time period with the value of 3.7 percent in the year 2018. The main difference between sectors presented in Figure 2 is the absorption of intersectoral technological progress spillover effect.

The textile sector managed to utilize technological progress spillover effect at the second part of the analyzed time period. Between 2007 and 2018, the annual technological progress growth rate, due to the effect of intersectoral technological progress, the spillover effect increased from 0.3 percent up to 0.8 percent. Still, intersectoral technological progress spillover effect in given simulation is weaker compared with results of sensitivity analysis, where technological progress growth rate was measured due to increase in gross profit values.

The last simulation is performed with labor productivity value increased by 10 percent for all companies operating in the Lithuanian manufacturing industry. The results of technological progress average annual growth rate due to this increase in labor productivity are presented in Table 5.

The same distribution of technological progress growth rates between sectors in the presented simulation is maintained as in the case of 5 percent labor productivity increase. The computers, electronics and optical devices sector managed to sustain the average technological progress growth rate of 8.7 percent all throughout the analyzed period of 2003–2018, while the second fastest growth rate was identified in the case of textile sector.

The sensitivity analysis suggests that gross profit and labor productivity measures affect technological progress development differently. Although an increase in gross profit values affects the average annual technological progress growth rates for all sectors operating in the Lithuanian manufacturing industry, while the increase in labor productivity influences technological progress growth for 15 out of 18 sectors, the effect of gross profit variable on technological progress is weaker compared to the effect of labor productivity.

The results of sensitivity analysis also suggest that growth in gross profit variable tends to generate intersectoral technological progress spillover effect more easily. An increase in gross profit values induced technological progress spillover effect in the case of 15 out of 18 analyzed sectors, while labor productivity growth resulted in significant intersectoral technological progress spillover effect for 9 out of 18 sectors operating in the Lithuanian manufacturing industry.

Discussion

The results obtained from the conducted research coincide with endogenous growth theory. According to the theory, every industry is dominated by a quality leader, which emerges from high level of labor productivity (Chu *et al.*, 2017). The expected monopolistic profit is shared across industries, thus suggesting that an increase in technological progress can be spilled over between industries. Bharadwaj *et al.* (2005) in their research emphasize the importance of knowledge spillover from one industry to another thus stimulating economic growth.

According to Lafi (2018), intra-sectoral technology spillover effect depends on specific characteristics of individual sectors. Positive technological progress spillover is statistically significant in the case of high-tech industries, while in case of low-tech industries foreign presence exerted crowding-out effect and business attraction effect through competition are present. This also coincides with the conclusions that the sectors which reinvest their profits into further technological development manage to utilize technological progress effect in the most efficient manner.

Iwasaki and Tokunaga (2016) also state that productivity spillover effect is lower than the direct effect created from internal managerial decisions of companies. This is confirmed by results of presented research: most of technological progress growth in performed sensitivity analysis is produced internally as spillover effect has a role of growth reinforcement.

According to Benos *et al.* (2015), growth spillovers play an essential effect in process of European Union regional development. Interregional externalities matter in European regions, independently from how neighboring borders are drawn between them. Thus, development policies should be directed at regions or sectors which are lagging behind, increasing physical capital and labor investments. In the case of the Lithuanian manufacturing industry, no such measures are needed as throughout time technological progress values of most sectors were increasing. Policies should help to create an environment where companies operating in the Lithuanian manufacturing industry could continue investments into innovation creation and further develop the technologies used in production processes.

Conclusions

To perform an assessment of intersectoral technological progress spillover, two methods were chosen: vector autoregression model and agent-based modelling framework. To begin with, vector autoregression model helps to determine the functional form of technological progress measures for each sector. Vector autoregression model permits the distinction of intersectoral technological progress spillover effect from the effect of internal factors on technological progress growth for each of the analyzed sectors operating in the manufacturing industry. After functional forms of technological progress measures are established, agent-based modelling technique helps to evaluate how changes in different parameters affect fluctuations of technological progress values in manufacturing industry sectors. This kind of sensitivity analysis allows to analyze how changes in various variables affect technological progress development in the manufacturing industry as a whole.

In the case of Lithuanian manufacturing industry, the constructed vector autoregression models indicated that variables influencing the development of technological progress measures the most are inflation-adjusted gross profit value and labor productivity measure. The conducted sensitivity analysis, performed on the basis of agent-based modelling framework, showed that these two parameters influence technological progress measure changes in a different way. Growth in inflation-adjusted gross profit values affects larger number of sectors operating in Lithuanian manufacturing industry while impact of labor productivity on technological progress values is stronger. The sensitivity analysis also revealed that in the case of sectors operating in the Lithuanian manufacturing industry, growth in inflation-adjusted gross profit measure is more prone to spreading via intersectoral technological progress spillover effect while labor productivity measure is more local to sectors operating in the Lithuanian manufacturing industry, mainly affecting technological progress values of sectors, which generated an increase in labor productivity by themselves.

The presented research suggests improved methods for analysis of technological progress values and evaluation of technological progress spillover effect in the case of manufacturing industries. Still, methodology used in this research paper could be improved. Some of independent variables could be replaced with more informative measures (for example, gross profit measure could be replaced with economic value-added measure, which would be a better parameter for the analysis of value creation in a sector). With a larger sample size of data, VAR model could include longer lag values while assessing relationships between technological progress measures and independent variables. Despite that, the presented methodology is a fitting framework for an analysis of intersectoral technological progress spillover effect, as no more detailed alternatives for an analysis of manufacturing industries are currently present.

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Annex

Table 1. Sectors of Lithuanian manufacturing industry and their identification codes

Code	Name	Code	Name
C10	Food products	C23	Non-metal mineral products
C11	Beverage	C24	Metal processing
C13	Textile	C25	Metal products, excluding machinery
C14	Apparel	C26	Computers, electronics and optical devices
C15	Leather and leather products	C27	Electricity equipment
C16	Timber products, excluding furniture	C28	Other machines and equipment
C17	Paper and paper products	C30	Other transportation equipment
C18	Printing and reproduction	C31	Furniture
C22	Rubber and plastic products	C33	Machinery repairs and equipment

Table 2. Growth of technological progress measure due to the increase of gross profit by 5 percent in the Lithuanian manufacturing industry

Sector	TFP growth from internal factors	TFP growth from spillover effect	Sector	TFP growth from internal factors	TFP growth from spillover effect
C10	0.67%	0.33%	**C23**	0.86%	0.85%
C11	0.45%	0.41%	**C24**	1.15%	0.20%
C13	0.81%	0.50%	**C25**	0.77%	0.38%
C14	0.56%	0.00%	**C26**	0.00%	0.15%
C15	1.77%	0.87%	**C27**	1.08%	0.34%
C16	0.57%	0.00%	**C28**	1.30%	0.79%
C17	0.00%	0.44%	**C30**	0.00%	1.15%
C18	0.85%	1.15%	**C31**	1.55%	0.81%
C22	1.04%	0.00%	**C33**	0.47%	0.67%

Table 3. Growth of technological progress measure due to the increase of gross profit by 10 percent in the Lithuanian manufacturing industry

Sector	TFP growth from internal factors	TFP growth from spillover effect	Sector	TFP growth from internal factors	TFP growth from spillover effect
C10	1.34%	0.67%	**C23**	1.72%	1.70%
C11	1.00%	0.72%	**C24**	2.29%	0.39%
C13	1.61%	1.00%	**C25**	1.60%	0.69%
C14	1.11%	0.00%	**C26**	0.00%	0.30%
C15	2.70%	2.57%	**C27**	2.17%	0.67%
C16	1.14%	0.00%	**C28**	2.60%	1.59%
C17	0.00%	0.88%	**C30**	0.00%	2.30%
C18	1.71%	2.29%	**C31**	3.09%	1.63%
C22	2.09%	0.00%	**C33**	0.95%	1.35%

Table 4. Growth of technological progress measure due to the increase of labor productivity by 5 percent in the Lithuanian manufacturing industry

Sector	TFP growth from internal factors	TFP growth from spillover effect	Sector	TFP growth from internal factors	TFP growth from spillover effect
C10	1.65%	0.04%	**C23**	0.00%	0.90%
C11	1.02%	0.22%	**C24**	1.66%	0.77%
C13	3.45%	0.43%	**C25**	2.21%	0.01%
C14	3.46%	0.00%	**C26**	4.34%	0.01%
C15	0.00%	2.62%	**C27**	0.00%	0.00%
C16	2.31%	0.00%	**C28**	0.00%	0.29%
C17	1.51%	0.98%	**C30**	0.00%	0.00%
C18	0.00%	1.17%	**C31**	0.00%	0.37%
C22	3.06%	0.00%	**C33**	0.00%	0.00%

Table 5. Growth of technological progress measure due to the increase of labor productivity by 10 percent in the Lithuanian manufacturing industry

Sector	TFP growth from internal factors	TFP growth from spillover effect	Sector	TFP growth from internal factors	TFP growth from spillover effect
C10	3.30%	0.08%	**C23**	0.00%	1.81%
C11	2.04%	0.44%	**C24**	3.31%	1.54%
C13	6.90%	0.87%	**C25**	4.42%	0.01%
C14	6.93%	0.00%	**C26**	8.68%	0.01%
C15	0.00%	5.23%	**C27**	0.00%	0.00%
C16	4.62%	0.00%	**C28**	0.00%	0.58%
C17	3.01%	1.96%	**C30**	0.00%	0.00%
C18	0.00%	2.34%	**C31**	0.00%	0.75%
C22	6.12%	0.00%	**C33**	0.00%	0.00%

Figure 1. Decomposition of technological progress annual growth rate due to the increase in gross profit measures for leather and leather products sector (A) and furniture sector (B)

A

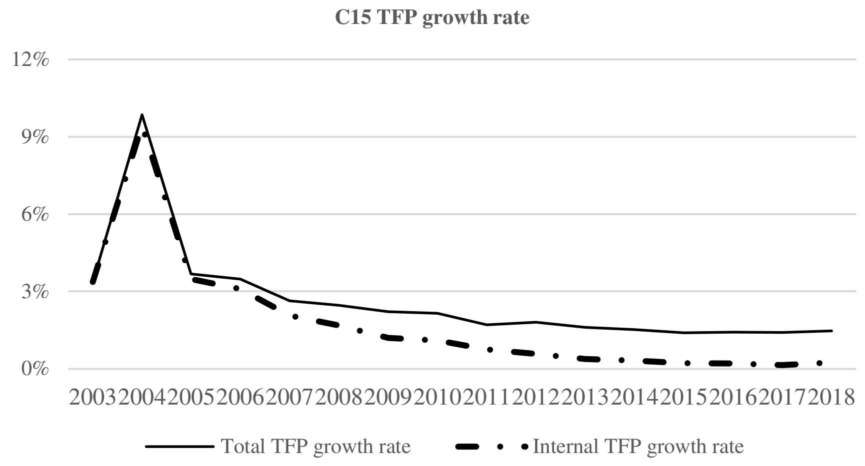

Figure 1. Continued

B

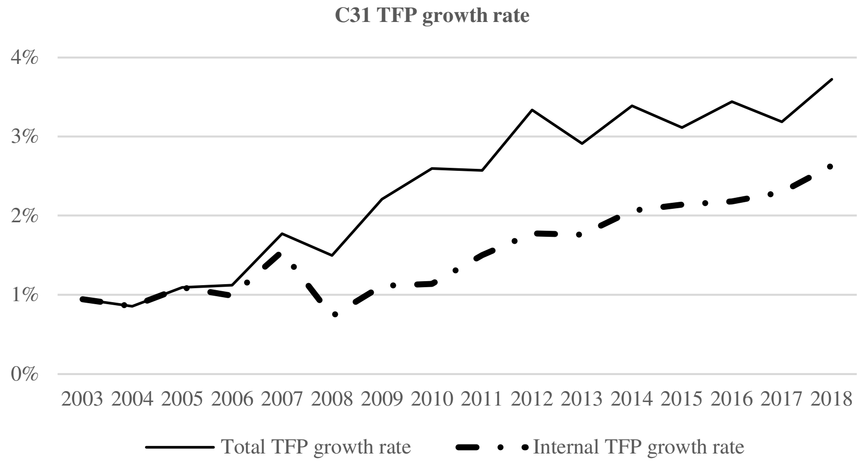

Figure 2. Decomposition of technological progress annual growth rate due to the increase in labor productivity measures for computers, electronics and optical devices sector (A) and textile sector (B)

A

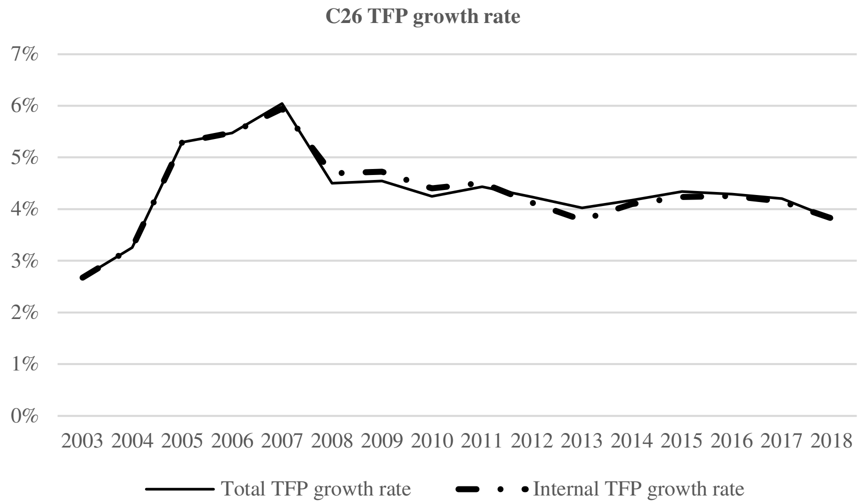

Figure 2. Continued

B