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# EFFECTS OF AUTOMATIZATION AND DIGITALIZATION ON FIRM LEVEL PRODUCTIVITY: A METALLURGIC INDUSTRY CASE STUDY

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I hereby declare that I have compiled the thesis independently

and all works, important standpoints and data by other authors

have been properly referenced and the same paper

has not been previously presented for grading.

The document length is 7442 words from the introduction to the end of conclusion.

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# TABLE OF CONTENTS

# ABSTRACT

In recent years, there has been a growing trend towards automatization and digitalization implementation. Previous researches state that automatization of activities and digitalization allow business organizations to improve their performance by preventing human error, facilitating a better informational exchange and many other. The main objective of the thesis is to analyse the impact of automatization and digitalization implementation on the metallurgic firm level productivity.

The research represents the main findings of the effects of digitalized equipment and automated machines based on the data of a metallurgic company collected on the period of the years 2000 until 2019. The method used for this research was selected to be a regression as it allows to observe the tendency of certain variables throughout the large period of time.

The results of the research confirmed positive effects of digitalization and automatization interaction on firm level productivity. In addition, the positive impact of export orientation and human capital intensity, as the additional factors, was demonstrated.

The analysis, however, showed that the implementation of automatization is much more efficient and influences the firm's performance significantly. Adoption of automated machines stimulates firm's better performance, increases revenues and allows to carry out larger amount of work in the particular time frame. On the contrary, digitalization as the independent auxiliary tool did not show any major effect on the particular firm's productivity.

In summary, the analysis suggests that integration of innovative technologies and automated machines into company's working process leads to the growth of its' productivity.



Keywords: automatization, digitalization, productivity, human capital, export orientation

# INTRODUCTION

Why do firms exist? There is a significant advantage to firms and it is the capability to mobilize multiple resources to solve very complicated problems. It especially carries weight in nowadays world when innovative technologies come in and open up unlimited opportunities to improve productivity and enhance revenues.

Successful businesses should necessarily set goals which generally are profit maximization, capture of a bigger market share and provision of good customer service. An auxiliary tool which facilitates achieving the goals mentioned above is information technology systems and automated machines. These innovations contribute to converting non-digital information into digital data and freeing humans from repetitive tasks in order to focus on more complex things.

To date, two specific and helpful terms represent this transformation - "digitalization" and "automatization". These expressions occurred in 1970s when first digital computers and digital record keeping were adopted. Clearly, as the development progressed, more and more scopes of activities were interested in digitalization and automatization implementation (Büttner *et al*. 2018). Obviously, this phenomenon has not spared the manufacturing environment. In manufacturing companies, the process of digitalization and automatization refers to improving and "upgrading" the working processes which include production itself, internal communication, warehouse management, sales process and other.

Despite the potential benefits for production efficiency, many manufacturing firms still refuse to admit the transformation and learn how to adopt it. The denial occurs due to the lack of knowledge and fear of the unknown. Accordingly, the desire to find out what is the actual impact of digitalization and automatization implementation on the firm productivity was the main motivator of thesis' topic choice.

Current research focuses on the identification of the effects of digitalization and automatization implementation while accounting for the additional factors such as human capital intensity and export orientation which are known as the influencers of the production efficiency. In order to capture the results, the following tasks were set: review the literature, collect the data, pick up

appropriate method for data analysis, interpret the results and find out whether digitalization and automatization are positively associated with firm's productivity.

In the present case, the manufacturing company OÜ Falkonet Metall which focuses on the metal furniture production is being described. In order to reveal a pattern, it was decided to analyse the effects of digitalization and automatization of the company on its productivity starting from the year 2000 when first implementations were made. In total, the number of observations resulted in 80, as the data was collected from the 20 years of operations on a quarterly basis.

As the research include time-series data, the vector autoregressive model has been chosen in order to conduct an analysis which points out the tendencies of certain variables and their relationship between each other. The presence of summary statistics and correlation matrix also allows to observe the data in more meaningful and precise way.

The thesis is divided in 3 main parts. First, theoretical framework is presented, the results of previous studies are discussed, research questions and hypotheses are formulated and the short description of the firm's activities is given. Second, data and methodology description are presented, the research process is described as well as the main descriptive statistics are demonstrated. Third, the regression analysis results are evaluated and the conclusions are presented. In addition, several limitations and suggestions for further studies are discussed.

# 1. THEORETICAL FRAMEWORK

## 1.1. Microeconomic theory

The goal of microeconomics is to understand what decisions individuals and firms make and what are their influencers (Tubaro, 2015). Further, emphasis is placed on the firms' decisions and peculiarities.

The firm is an institution in which its inputs (machines, labour, human capital and territory) create outputs (products, services and commodities). On the basis of microeconomic theory, the firm is able to maximize its profits if it provides that amount of outputs whose marginal cost is equal to its marginal benefit (revenue). Under these circumstances, the firm is taking a decision whether to expand production or reduce it.

The following part of the theory describes the fact that firm operates in two different time frames: short-term and long-term. The long run is distinguished by the fact that no fixed costs exist, each factor of entire production becomes variable. In contrast, in short run at least one input is fixed and all the others remain variable. The most commonly fixed variable is capital (land, machines and other durable inputs) (Mas-Colell, 2010).

More modern approach distinguishes between firms that rather work to complete their long-term goals (maintain sustainability) and those who concentrate on short-term objectives (make profit) (Backman, 2013). The theory also manages decision making in numerous areas such as resource allocation and production techniques.

Moreover, the theory focuses on different types of market: monopolistic, oligopolistic, imperfectly competitive and perfectly competitive. Current research describes a firm which belongs to the imperfect competition market. In this type of market, firms are able to influence and change the price of the products, thus they are the price makers (similarly in perfectly competitive market firms are price takers). Imperfect competition has many features of perfectly competitive market, for instance, free entry/exit and existence of other similar firms, however it has got one monopolistic element: firms make differentiable products. The output differs in brand name, quality, durability and size.

Above all, the theory gives an explanation concerning cost reduction in firms. The cost minimization is achieved by choosing carefully how much of each input to employ in such way that the costs of producing particular products are minimized (Karaivanov, 2017).

The existence of the Schumpeter's theory of economic development is also related to the topic being examined. The theory indicates that the growth of outputs depends upon the growth of productive factors as well as technology. According to Schumpeter, profits can arise if innovations (technologies) are introduced. Hence, the change in technological knowledge and its implementation is responsible for the changes in the stock of manufacturer products (Langroodi, 2017).

## 1.2. Importance of implementation digitalization and automatization in metallurgic industry

Digitalization in business means the usage of technologies in order to change and develop its model and provide unique revenue opportunities. In general words, digitalization implemented in a particular organization gives a huge advantage in front of competitors and makes the business itself faster, better and stronger (Arora, 2018).

Another process which is also applied in many businesses is automatization which means the usage of technology, however for other purposes. It is done by replacing manual effort with up-to-date technologies which can fulfil the tasks in order to minimize the costs and achieve higher efficiency (Achuthan, 2019).

The importance of these two processes is obvious in nowadays world. It would be difficult for a business to survive while not implementing emerging technologies which can prevent human error, facilitate a better informational exchange between co-workers, manufacturing processes and clients. Moreover, digitalization and automatization save data storage, reduce operational costs and enable to stay in contact with a person from any part of the planet (Rolson, 2018).

The following table gives a short overview on the main aspects of digitalization and automatization inter alia the description, main examples and the very general effects.

Table 1. Aspects of digitalization and automatization

| Aspects | Digitalization | Automatization |
|---|---|---|
| Short description | Describes the implications of information technology assistance, new communication software | Describes the implementation of robotics, technology and tools to accomplish a task without manual effort |
| Examples (in different industries) | Machine learning, artificial intelligence, mobile apps, computer software, management systems | Robotics, automated warehouse management systems, machines, press working operations |
| General effects | Linkage of different kinds of activities inter alia communication, organization, management | Acceleration and strengthening of working processes without human interference |

Source: Automation, digitization and digitalization and their implications for manufacturing processes (Schumacher A. et al. 2016)

Innovative technologies and automated machines have become the “heart” of many business strategies. They provide new ways of communication, collaboration, execution and production in each industry.

Metallurgic industry is one of the most versatile and mobile industries and therefore is highly in need of automatization and digitalization solutions. Every metallic product requires accuracy and precision down to the tiniest detail. The process of product creation itself consists of several stages (Appendix 2).

“When technology works in perfect harmony with the different aspects of metal production, the effect can be compared to the performance of an orchestra” (Iijima, 2018). An orchestra has a range of musicians where each of them plays a huge individual role, however instruments sound in unison. Analogous, a well-organized and productive metallurgic plant consists of numerous components that need to operate conjointly in order to achieve full potential.

The examples of automatization solutions can be industrial robots that meet very demanding requirements of metallurgic industry such as working in very torrid or damp environments (Automation in metal industry, 2019).

An illustration of digitalized metallurgic enterprise is total transparency protected by information technology systems, so in case an emergency situation occurs, plant can be alerted automatically and later on adjusted by needed parameters to continue the working process. The examples of digitalized enterprise are possession of such technologies as supply chain management systems, artificial intelligence, enterprise resource planning system, cloud computing technologies, customer relationship management system and many other.

## 1.3. Previous empirical research and results

As the theme of digitalization and automatization is very asked for and actual, many research articles have been written during the last years (Amorim *et al.* 2018). However, the same processes used in metallurgic industry have been researched insufficiently. In connexion with this, it is essential to analyse the implementation of digitalization and automatization generally in manufacturing industry and afterward implement the knowledge and go behind the features and nuances of the same processes in manufacturing metallurgic industry.

In recent years, term Industry 4.0 has been used very commonly. It indicates the trend towards digitalization and automatization in the manufacturing environment (Oesterreich and Teuteberg, 2016). Despite the fact that Industry 4.0 has got many potential benefits in terms of productivity and quality improvement as well as huge time saving, insufficient attention has been paid to this concept.

Previously conducted researches state that the journey towards digitalization and automatization is a long road. Unconsciously jumping into technical matters without prior investigation may be problematic, the lack of knowledge is still an obstacle (Machado *et al*. 2019).

To date, however, based on the numerous questionnaires and surveys the vast majority of the business' representatives report that their organizations have already deployed software to automate business tasks and responsibilities (Muscolino, 2019).

Automatization of activities and digitalization allow business organizations to improve their performance by eliminating simple errors, increasing the speed of reaching objectives and sometimes even achieving the results which go beyond human capabilities. Based on the previous researches, it is proved that automatization and digitalization can enable productivity growth on two levels. Firstly, the benefits may be gained on the individual businesses level. Secondly, it influences the level of entire economies where leap in productivity is strongly needed as the percentage of the working-age population is dropping in many countries (Manyika *et al.* 2017).

Since the productivity of firms is treated as the most important factor that identifies its economic wellbeing, it is necessary to study which aspects influence it. It is known that the most significant role on the firm's performance usually play its own resources and attributes. One of these internal resources are staff members with their knowledge, experience, level of education and other qualities. The results of previous researches show that highly educated employees with good cognitive skills positively affect firms' productivity (Jäger *et al.* 2015).

A lot of comparison researches have been conducted in order to establish the relationship between exports and productivity at the plant-level. The results can be summarized as follows: firms who have started exporting their products have showed better performance in comparison with non-exporters. Explicitly, firms that practise export have reached higher productivity (in terms of total factor productivity), larger size (in terms of number of employees) and higher wages (as a result of higher skills) (Miyakawa *et al*. 2015).

The more specific article which is related to the examined topic was conducted by Procedia Manufacturing and focuses on the effects of digitalization and automatization on German manufacturing companies. The results of the study document that "both automatization and digitalization display statistically significant positive effects on labour productivity" (Horvat *et al.* 2019). It has also been highlighted that both technological implementations boosted production efficiency considerably (when looked at separately).

The results of the research mentioned above might be ambiguous as the study consisted of many additional factors such as firm size and sectoral attribution. However, current research focuses only on one Estonian manufacturing firm and this fact automatically eliminates many additional factors.

## 1.4. Description of OÜ Falkonet Metall

The main line of business of Falkonet Metall OÜ nowadays is the manufacture of a very large range of metal furniture for facilities, hospitals, hotels, shopping malls, kindergartens, schools and etcetera. The company is 100 percent based on Estonian capital and has two owners.

OÜ Falkonet Metall started its manufacturing process in the spring 1999 when the founders decided to produce secure doors.

The first production facility was a modest manufacturing plant with limited capacity that was located in Miiduranna. The firm started experimenting with the production of industrial furniture and continued increasing the amount of manufacturing secure doors.

By the beginning of the year 2000, the company has grown to such degree that Miiduranna plant was not capable to manufacture necessary amount of furniture. For this reason, the owners of the company had to search for a larger space. A needed facility was found in a place called Aruküla.

The period of 1999-2001 occurred to be very important for the company: the realization has proved that the initial business idea transformed into a real success. As the company was able to offer a high-quality product for a reasonable price, the average amount of orders grew up to 400 doors per month.

A new factory and successful door-business gave the opportunity to continue developing the line of manufacturing metal furniture. As the time passed, Falkonet Metall OÜ managed to obtain some huge orders in Estonia and increase its revenue.

By 2002 the demand for metal furniture increased to such level that it was not possible to work using existing machinery, so the owners decided to invest into new equipment. The amount of investment resulted to be 6.5 million kroons which is considered to be a huge amount at that time.

The first major clients from the foreign market were Prewo AB from Sweden and Lindström OY from Finland. As the percentage of export, especially to Sweden and Finland, continued to rise, in the year 2003 it was decided to put all available resources and efforts into manufacturing metal furniture and totally avoid secure door production.

By 2004 the economic indicators of the company became so good, that it has helped to receive recognition from local finance companies as well as from partners outside Estonia.

In 2006 Falkonett Metall OÜ ranked in the top 100 Estonian Furniture Producers by AS Äripäev. Moreover, Falkonett Metall OÜ was recognised (2006- 2019) by AS Krediidiinfo and Experian with the Certificate of a Successful Estonian Company with the rating AAA (excellent). This rating is an assessment of a company expressed as a cumulative grade based on economic and financial behaviour.

At the moment the company has 69 employees of which the majority are engaged with the production and only 13 people are from administration department which includes sales and accounting department and is managed by the executive director. To date, the majority of workers have got secondary education and extensive experience (Appendix 1).

The goal of the company is to sell its products directly to consumers in Estonia, Finland, Sweden, Latvia, Lithuania and Russia.

The mission of Falkonet Metall OÜ is to offer a high-quality product with the affordable price in all nearest countries.

Throughout the years, the firm has made several huge investments. It involves the acquisitions of high-value and massive automated machines. They are capable to carry out repetitive tasks by bending and carving metal, drying finished products. In addition, Falkonet Metall OÜ has installed and updated numerous software and programs on an ongoing basis (technologies as supply chain management systems, cloud computing technologies, customer relationship management system). Moreover, the company has expanded its territory, acquired real estate and invested in stocks.

## 1.5. Research questions and hypotheses

It is said that implementation of digitalization and automatization in a company's working process will lead to the increased manufacturing performance (Kroll *et al.* 2018). This raises a question whether implementation of digitalization and automatization truly supports and increases firm's productivity and to what extent. The author's objective is to answer the following questions: "Are automatization and digitalization positively associated with labour productivity in the metallurgic company?" and "Is human capital intensity in connection with

implemented digitalization and automatization positively associated with labour productivity?".

The measurement of the effects of process innovations (i.e. implementation of automatization and digitalization) is a complex issue. The main reason is that innovations in digitalization and automatization cannot be measured directly or immediately linked to any indicators. In contrast, they focus on process-related performance aspects (e.g. quality and efficiency) (Wheelwright *et al.* 1992). Hence, the processes of automatization and digitalization affect overall relation of outputs to inputs. This effect can be assessed by the productivity measures. At the level of the individual enterprise, the most commonly used measure is labour productivity (Kroll *et al.* 2018).

Labour productivity, also known as workforce productivity, is defined as real economic output per labour hour or labour unit. Thus, it evidently expresses the efficiency of human resources used in a particular company. Therefore, the foregoing leads to the first hypothesis.

H1: Digitalization and automatization are positively associated with labour productivity.

Another important factor which goes in connection with increased digitalization and automatization is human capital. As it was said in the previous investigations, human capital intensity stimulates higher productivity. The process of installing, managing and using information technology systems and robots directly interacts with workers. Thus, their education, experience and useful skills contribute to the high performance of the company.

Education, in general, increases the likelihood that a person will be able to adapt to technological changes and innovations. Another common human capital area is constant trainings and skills development. Different ways of trainings teach employees modern approaches, improve skills and provide information about the nuances and details of a specific field. Thus, human capital can be measured by previous experience and formal education. Hence, the foregoing leads to the second hypothesis:

H2: Human capital intensity in connection with implemented digitalization and automatization is positively associated with labour productivity.

The following parts are going to clarify whether to accept the hypotheses or reject them.

# 2. EMPIRICAL METHODOLOGY AND ANALYSIS

## 2.1. Data

To conduct an analysis which points out the effects of digitalization and automatization on a manufacturing company's productivity, the author made an empirical research based on the data from OÜ Falkonet Metall archives and Business Register source. The objective of this empirical research is to collect data related to firm's performance, mark in which period of time any technological changes were made, monitor any kind of modification and reveal what role digitalization and automatization played in this issue.

The study provides a large set of data on a particular enterprise including general company data, annual reports (labour cost, weighted average number of employees, revenue), human capital, innovative production technology, export orientation. In view of the foregoing, the existing data allow to reveal the effects of digitalization and automatization on the company's performance.

The sample was compiled from OÜ Falkonet Metall database and describes company's activities and decisions on the past 20 years. As the company has been producing metal furniture for a quite short period of time, the data was received on a quarter basis (1/4 of total year) which gives in total 80 observations. Further, the main independent and dependent variables will be provided and described.

Dependent variable: labour productivity (efficiency and performance indicator)

As it was discussed in the theoretical section, the measurement of production efficiency is presented in terms of "labour productivity". The figures in order to reveal it were calculated by gathering the inside information: "turnover quarterly", "average number of employees quarterly", "costs quarterly". The data on these parameters were collected through reviewing archives, calculating and investigating registers.

Independent variables: "digitalization", "automatization" (main explanatory factors)

The most important factors that should be included in the analysis are the digitalized equipment and automated machineries themselves. As the firm throughout the years of its operations has been implementing both, then two variables are presented in the current research.

The first is called “digitalization”. Under this term supply chain management systems, cloud computing technologies and customer relationship management system are meant. Their existence, implementation and usage are being analysed.

The second variable is named “automatization”. Under this term two key type technologies are being taken into the consideration. Industrial robotics and machines as well as automated warehouse management system are implied.

Both variables are measured in amount of purchase (EUR) in two ways. One data column represents exclusively acquisition costs on a quarterly basis cumulatively. The second column is related to the depreciation subtracted from the acquisition costs based on the same time period, thus indicating the net value.

Independent variables: human capital, export orientation (additional factors)

As the implementation of automated machines, robotics, information technology systems are directly influenced by the people who manage them, human capital is one of the additional independent variables. Firm’s human capital intensity is being measured in two categories: education level and amount of experience. Education level is identified with the proportion of staff that has at least three years of higher education since, in general, the duration of university studies is three years in Estonia. Experience is measured as the employee’s average number of years worked after finishing the studies.

It is common that researchers, who analyse company’s performance, also consider such factor as export orientation. In this case, export orientation is taken as an additional variable which is known as the influencer of technical production efficiency (Amorim *et al*. 2018).

## 2.2. Methodology and research progress

### 2.2.1. Methodology

There are numerous approaches how to conduct an analysis. The most suitable technique in this particular case is a regression analysis. It is convenient and ostensive in order to estimate the relationship between dependent variable and a collection of independent variables (Güler and Uyanik., 2013).

With a view to the production efficiency, the analysis could be done by using the time-series regression analysis since the data is in the time-series format. The main goal of this method is to derive the dynamic pattern in the collected data to estimate the effect of specific decisions and investments. Applying this method is possible and efficient as the gathered data is in a series of particular time periods (in this case quarters). The data in current research is considered to be time-series as there is a data on a few variables collected at different points of time (Statistics Solutions, 2020).

### 2.2.2. Research progress

The process of analysis consisted of several steps. Firstly, author's objective was to find all necessary data corresponding to the aim of the research and specific time frame. It required searching for the documentation in firm's archives, close communication with OÜ Falkonet Metall's accountant as she has all the accesses to the Business Register and data storage.

Secondly, after obtaining the data to work with, it was essential to choose which information actually relates to the researching topic. As quarterly reports contain a huge amount of data, the main and most important indicators were taken into account. It should also be mentioned that on the 13$^{th}$ of July 2010 the Council of the European Union has accepted Estonia's request to join the euro area starting from the 1$^{st}$ of January 2011. Thus, all the data of OÜ Falkonet Metall's performance prior to the entry into euro zone must have been converted to the euro from kroon at the fixed conversion rate, which equals 1€ = 15.6466 EEK (European Central Bank, 2010).

The third stage of the analysis was dedicated to structuring all the data in such order that it would be easily understandable, readable and suitable for further analysing. It was decided to create an Excel file which would contain the structured data. It included revenue, labour cost, average number of employees, export, procurement of automated machines and installation of information technology systems and their acquisition costs columns presented quarterly. Moreover, the tables related to the education level and the experience of employees were formed.

Further, for a better visual representation, several linear charts were structured that help to notice trends over selected period of time (80 quarters).

The next step involved choosing the right platform in order to conduct the regression analysis keeping in mind that the data is time-series. Taking this fact into the consideration, it was decided to choose Gretl (Gnu Regression, Econometrics and Time-series Library) software which is an open-source statistical package.

Later, the analysis was conducted and the results were evaluated and interpreted.

## 2.3. Descriptive statistics

Descriptive statistics have huge importance since simply presenting the results of raw data is hard to understand and visualize. Descriptive statistics allow the reader to see the data in more meaningful way and lead to quicker understanding. The descriptive statistics are often divided into two parts: measures of central tendency and measures of variability. Measures of central tendency commonly include minimum value, maximum value, mean, median. On the opposite, standard deviation, variance and skewness belong to the measures of variability (or spread).

Further, the main descriptive statistics are illustrated on each of the variable:

Table 2. Descriptive statistics.

| | Labour productivity | Automatization | Digitalization | Human capital intensity | Export orientation |
|---|---|---|---|---|---|
| Min | 468.3 | 0 | 54.6 | 2950.54 | 0 |
| Max | 15044.25 | 1202605.3 | 125000 | 72000 | 1382734 |
| Mean | 4639.1 | 224924.7 | 20624.9 | 24187.44 | 549848.5 |
| Median | 3958.3 | 179872 | 16047.81 | 16375.33 | 579619 |
| Standard deviation | 2980.3 | 228710.8 | 22658.29 | 18735.03 | 323544 |
| Sample Variance | 8882162 | 52300000000 | 513000000 | 351000000 | 105000000000 |
| Skewness | 1.3 | 2.4 | 3.3 | 1.1 | 0.1 |
| Count | 80 | 80 | 80 | 80 | 80 |

Source: author's calculations in Gretl software

Each of the variables count on 80 equally divided quarters. All of them are positively skewed, which means distribution is tilted to the right and the mean of the observations is greater than the mode.

The mean indicator of automatization and digitalization is very representative in current analysis. The mean of acquisition costs of automated machines is 10 times greater than the acquisition costs of digitalized equipment. Therefore, it can be concluded that, first, implementation of automatization tools is much more expensive than implementation of digitalized equipment. Second, the analysed firm focuses more on production improvement and facilitation and acquires a lot of robotics.

The standard deviation tends to be a great number in all of the presented independent variables. Thus, it explains that data is widely spread out from the mean. The justification for this phenomenon is that in certain quarters of the year firm acquired costly equipment and some quarters tended to be quiet and did not have any innovations. The huge standard deviation in the export orientation column is due to the big change in company's sales orientation. During

the primary years of existence, the firm focused on the local market. However, as the company expanded and attracted new customers, the focus started to be on the foreign market.

The minimum value of export and automatization is equal to zero. In this particular case, it signifies that at the beginning of the company's activities, firstly, sales accounted only for the local market and the access to abroad was obtained some years later. Secondly, the first implementation of automated machines happened after 3 years of company's existence as it was a huge money investment.

All of the independent variables to a greater or lesser extent influenced the behaviour of the main dependent variable.

The development of labour productivity on a quarterly basis:

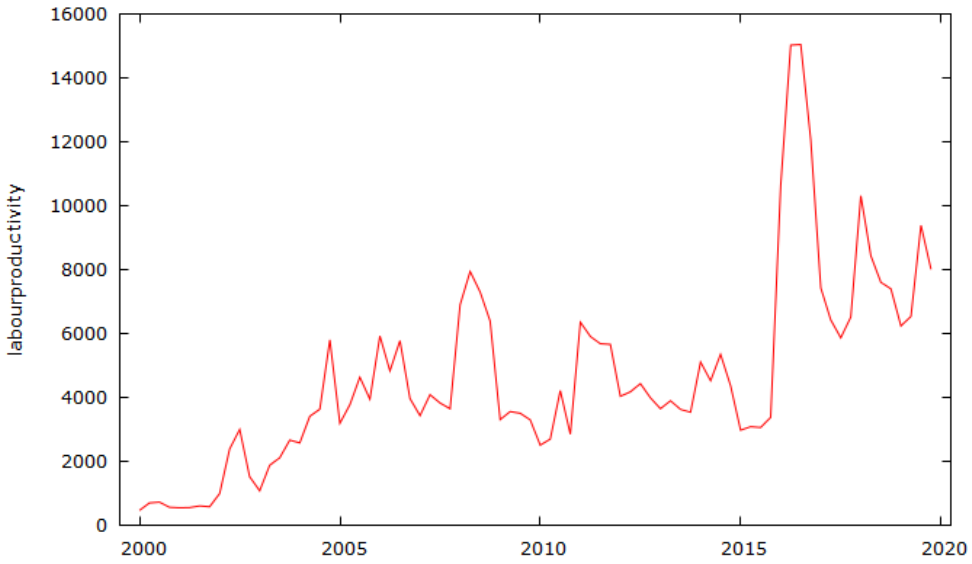


Figure 1. Time-series plot of dependent variable. Source: author's calculations

The Figure 1 demonstrates the growth in labour productivity with numerous fluctuations over the past 20 years. Analogous, the quantity of digitalization and automatization tools implemented into the company's working process has been rising throughout the years.

Although, a growth in labour productivity can be observed, the data also has permanent seasonal variations. It was proved that each year first quarter shows worse results comparing to the rest quarters despite the fact that some digitalization and automatization implementations were still made at that time. This fact can be explained as usually at the beginning of the year working capacity declines, a lot of employees are still on the vacation and interest in metal furniture purchase subsides.

Obviously, the firm does not implement expensive information technology systems and automated machines each quarter as the monetary contribution is huge. However, OÜ Falkonet Metall still pays a certain amount of money quarterly for already implemented digitalization and automatization tools' maintenance and enhancement. The sum varies depending on the fact whether any renovation works were made (Appendix 3, Appendix 4).

Besides the main explanatory variables, 2 additional variables were also included into the time-series regression analysis – human capital and export.

It is important to mention that the firm is very export-oriented as the large amount of total sales account for neighbour countries – Finland, Sweden, Latvia and recently joined Russian Federation. Thus, the expansion of foreign clients has played a positive role on company's performance (Appendix 5).

Throughout the years, the quantity of workers has been gradually rising. During the observation time, the average number of employees increased in nearly three times. A larger number of workers has obtained secondary education, however their desire to develop and improve themselves was huge. Based on the data collected from the firm, the human capital intensity (observing from the year 2000) has grown significantly (Appendix 6).

It is essential to pay attention to the fact that the majority of employees who joined the company from its very early stages of development have stayed up until now, thus they have gained decent baggage of experience and are able to share their knowledge with young colleagues.

There was a special model structured in order to calculate human capital intensity in the firm for the last 20 years. The experience was measured in terms of years worked. The education was calculated on the basis of educational qualifications. Their combination resulted in a clear illustration of human capital intensity rise (Fender and Mallett, 2016).

# 3. THE DISCUSSION OF ANALYSIS AND RESULTS

## 3.1. Effects of digitalization and automatization on firm's productivity

The regression analysis is commonly used and highly important as it helps businesses to understand the data they have and use it to make the right and valuable decisions. The time-series regression analysis that was conducted, accounts for the independent variables and their impact on the labour productivity.

The presence of time-series plot (Appendix 7) is used in order to have the general visual representation of trends and changes in variables movement over time. From the first sight, similar trends can be visible in automatization, digitalization and export orientation variables. Moreover, all the variables are showing positive tendency.

The regression results are based on the 80 observations made on a quarterly basis starting from the first quarter of the year 2000.

Model used: time-series vector autoregressive model.

"The vector autoregression model is one of the most successful and flexible models to use for the analysis of multivariate time series" (Zivot and Wang, 1989). The vector autoregression model is considered to be especially helpful for revealing the tendencies of financial time series data.

The presented model in current research is described by four independent variables (automatization, digitalization, export orientation and human capital intensity) and one dependent variable (labour productivity). The main goal of this specific model is to describe the evolution of a number of variables and their relationship on the same sample period.

Platform used: Gretl software.

Gretl allows to use time-series methods, construct different kinds of graphs and equations, identify the relations between variables. It also helps to analyse the data by presenting summary statistics, correlation matrices and many other.

Table 3: The results of time-series regression analysis

Dependent variable: labour productivity

| | Coefficient | Standard error | T-ratio | P-value |
|---|---|---|---|---|
| Constant | 2.80 | 0.41 | 6.81 | 2.25e-09 *** |
| Automatization | 0.12 | 0.05 | 2.44 | 0.0169 ** |
| Digitalization | 0.03 | 0.02 | 1.55 | 0.1253 |
| Human capital | 0.36 | 0.05 | 6.72 | 3.33e-09 *** |
| Export orientation | 0.04 | 0.02 | 2.32 | 0.0232 ** |

Source: author's calculations in Gretl software

Table 4: The main indicators of the regression analysis

| | |
|---|---|
| R-squared | 0.86 |
| Adjusted R-squared | 0.85 |
| Rho | 0.83 |
| S.E. of regression | 0.162431 |
| Durbin-Watson | 2.043647 |

Source: author's calculations in Gretl software.

As the current data sample had several outliers which significantly influenced the model structure and thus the results of it, it was decided to use a log transformation. It is known to reduce the influence of those observations. The transformation is valuable as it makes patterns in the data more interpretable (Roka, 2019).

Moreover, a log transformation is very helpful for the measurement of comparison data as it is the only method where differences on the transformed scale have the meaning on the initial scale (Carstensen, 2010). Thus, the scaling problem that often exists in the regressions and invalidates them, does not violate the process of analysis anymore.

There are several important indicators on which to account for while interpreting the results. Firstly, p-value is being analysed. A low p-value indicates (p-value less than significance level (0.05)) that there is a statistically significant relationship between the dependent and independent variables. "Statistical significance" is the likelihood that the relationship between certain number of variables has occurred not by chance. Based on the results of the time-series regression, all the independent variables except "digitalization" have shown a strong effect on

labour productivity. A significant p-value for the constant (2.25e-09) shows that there is sufficient evidence to ensure that the constant does not equal to zero.

Secondly comes the R-squared which is frequently considered as the next most important indicator after the p-value. R-squared is known as the measure that represents the proportion of the variance for dependent variable that can be explained by the independent predictors. Presented regression shows that 86% of "labour productivity" is explained by "digitalization" and "automatization", "human capital intensity" and "export orientation" (which is relatively high).

Thirdly, the adjusted R-squared is presented in the current analysis. It is used to account for the predictors that are not powerful and significant in the regression model. A lower adjusted R-squared in this case states that the extra input variables are not improving the model and do not add any value to it.

Further, the constant (or y-intercept) of presented regression analysis is equal to 2.8 (measured on a logarithmic scale). It can be described as the mean response value when all of the predictors (or independent variables) are equal to zero.

The standard error of regression helps to obtain a confidence interval for the predicted values. The lower the indicator of standard error, the better as it reflects the average error of the model used. Current analysis showed that standard error equals to 16.2%.

Moreover, Durbin-Watson indicator is presented as it detects the presence or absence of autocorrelation. Current model shows that Durbin-Watson statistic is a few hundredths greater than 2. The result of "2" signifies that there is no autocorrelation found in the sample.

In order to summarise all the discussion presented above, the correlation matrix has been constructed. It helps to observe the correlation coefficients between the variables (in this case all variables with statistical significance were elected) (Pham-Gia and Choulakian, 2014).

Table 5. Correlation matrix

| Labour productivity | Human capital | Export orientation | Digitalization | Automatization | |
|---|---|---|---|---|---|
| 1.0 | 0.8389 | 0.7476 | 0.5649 | 0.7904 | Labour productivity |
| | 1.0 | 0.5548 | 0.6905 | 0.7609 | Human capital |
| | | 1.0 | 0.6471 | 0.75 | Export orientation |
| | | | 1.0 | 0.92 | Digitalization |
| | | | | 1.0 | Automatization |

Source: author's calculations in Gretl software

The Table 5 states that the relationship between all the presented variables is positive as the coefficients are all with "+" sign. It signifies that when a value of one variable increases, the value of the other variable also tends to grow. The dependent variable "labour productivity" is strongly and positively associated with all the independent variables (with statistical significance). The best indicators, however, can be observed in two connections: between digitalization and automatization, and between human capital and labour productivity.

Generally, the closer the coefficient is to "1", the stronger the relationship is.

## 3.2. Discussion of results

With a view to hypothesis 1, vector autoregressive model documents a positive effect of automatization implementation on labour productivity. It means that adopted automated machines inter alia industrial robotics, automated machines and automated warehouse management system are beneficial for the presented company and lead to its' higher labour productivity. Implementation of automatization adds efficiency, quality control, time saving and coherence to the firm's activities. Hence, it improves every stage of working process.

Worker's safety is an important aspect and it makes implementation of automatization even more valuable. Since manufacturing environment implies hard manual labour and sometimes even hazardous conditions, automated systems often protect employees from their common dangerous workplaces. In general, automatization technologies (if used wisely) are very helpful.

On the contrary, the same model did not show any significant effect of digitalization implementation on firm level labour productivity. This can be explained by saying that current company has not still reached its' highest level of innovative information technology systems adoption. Although, the company has installed the basic digitalized equipment (supply chain management system, cloud computing technologies and customer relationship management system), they are still considered as a novelty and do not account for the increase in productivity.

The main focus is on the automated machines acquisition as the production process is the most time-consuming and difficult part of the company's work. Moreover, gathered data state that the amount of sales has increased enormously which creates additional load on the production hall.

Oppositely, the number of office workers who deal with purchase orders, communication with the clients, accounting and designing the products (and should be using different kinds of digitalized equipment) has never exceeded 15 people. Thus, their internal communication and database are shared and transferred without any obstacles. Truly speaking, in most of the cases, they prefer face-to-face communication and live discussions, they rarely practice home-office.

The same model illustrates that the parallel use of robotics and digital technologies still enhances the firm's productivity. It is often difficult to distinguish the brink where automatization ends and digitalization starts. Thus, their combination is certainly useful.

The model also accounts for the human capital intensity and export orientation besides the main explanatory variables. The results of this time-series regression demonstrate the positive impact of both – human capital intensity and export orientation. As the time moved on and the number of employees increased, human capital intensity also tended to rise. The years of experience grew for many employees and new educated employees came in and have started to work on firm's development. Moreover, the company has totally changed its sales orientation. In early 2000s export accounted only for 20-30% of total sales. However, at the present moment, the export orientation of OÜ Falkonet Metall has reached nearly 70%.

With a view to hypothesis 2, the regression analysis stated a positive result of human capital interaction with digitalization and automatization which were positively associated with productivity. Both indicators were increasing as the time passed. More educated and experienced workers tend to adapt to the innovative technologies and automated machines quicker and have sufficient knowledge to use and maintain them.

Thus, the results of current research confirm the conclusions and opinions of previously conducted studies in this field with the exception of digitalization which did not show significant relation to labour productivity (when analysed separately).

## 3.3. Limitations and suggestions for further studies

No research is completely impeccable or comprehensive of all possible aspects. The current study represents the effects of digitalization and automatization implementation on productivity of a certain company on a specific period of time. Undoubtedly, it would be more useful to conduct an analysis comparing a few successful and well-known Estonian companies specialising in metallurgic industry, their investments in innovative technologies and automated machines and the outcomes of these decisions. It could be achieved by conducting the research using panel data (that includes time-series and cross-sectional data) setup. However, there is insufficient number of sources that provide needed information. The access to companies' data is usually given to its owners and workers. Therefore, the empirical part consisted of one company's information and its analysis exclusively.

It would have also been helpful to conduct a survey with the researching company's director in order to reveal preconditions to invest in different automatization and digitalization tools which cost substantially. However, due to the situation that is being faced today, it was inconvenient and not timely. It is understandable as the head of the company has to deal with the issues of working process and financial support.

The current research was conducted on the example of Estonian manufacturing company which operates in metallurgic industry. However, it would be also educational to conduct the similar analysis on the example of other European (or neighbour) countries. Moreover, it would be informative to compare the analysed industry with other ones, for instance health care or education industries.

Besides the apparent benefits and convenience that digitalization and automatization bring to the companies' lives, the innovative technologies and automated machines have got several disadvantages. Some academic sources state that adoption of automatization and digitalization may lead to the increase in unemployment and unpredictable costs in the future (Blue, 2015). It is also believed that excessive usage of automated machines may lead to the increased pollution and emissions being harmful to the environment and ecosystem. The above leads to the conclusion that adoption of innovative technologies and automated machines should be carefully managed, controlled and researched further.

The truth is that many additional factors play a huge role in companies' performance besides the automatization and digitalization implementation (for instance, human capital intensity, firm size, export, number of employees and many other).

In general, the issue of the usefulness of automatization and digitalization implementation should be analysed on each specific example separately as there are many factors that influence the implementation of innovative technologies and automated machines.

# CONCLUSION

The research was dedicated to the analysis of the effects of digitalization and automatization on the firm's productivity based on the data which was collected from the OÜ Falkonet Metall archives and Business Register source. The analysis was conducted in the specific time frame which accounts for the period 2000-2019. In a sense, this research provides the new and raw findings which can be used in future analyses on the larger data sample and amount of companies.

The current study tested two following hypotheses:

1. Digitalization and automatization are positively associated with labour productivity;
2. Human capital intensity in connection with implemented digitalization and automatization is positively associated with labour productivity.

Both hypotheses were confirmed. Hence, the research can provide the following main findings:

- First, the data collected indeed states an adoption of automated machines and digitalized equipment in large numbers and on an ongoing basis.
- Second, the processes of digitalization and automatization cannot be considered as a recent trend in the presented company since the first implementations were made already in the early 2000s.
- Third, the strong and positive effects of automatization on firm's productivity were confirmed. Adoption of automated machines stimulated firm's better performance, increased revenues and allowed to carry out larger amount of work in the particular time frame.
- Fourth, digitalization as a separate innovation tool has not proved any significant positive impact on the firm's productivity.
- Fifth, automatization and digitalization intertwined simultaneously reinforced each other and thus were positively affecting the productivity of the analysed firm.
- Sixth, the presented model highlighted the importance of the additional variables. Export orientation and human capital intensity were considered as huge supporting

factors which resulted in a better automatization and digitalization implementation and the performance of the company in general.

As a whole, the research fulfilled its task and stated that trend towards digitalization and automatization is justifiable. Automated machines in connection with digitalized equipment indeed ease the firm's working process including workload of production hall employees, providing better communication conditions, lightweight results monitoring. Additional support from increased human capital maintains the easier and quicker digitalization and automatization tools adoption. Bigger export orientation resulted in better performance having reached higher productivity, employing larger number of workers and paying higher wages to them. Overall, the research provides ample evidence that revolution of innovative technologies and automated machines increases the productivity of the metallurgic firm on the example of OÜ Falkonet Metall.

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# APPENDICES

## Appendix 1. OÜ Falkonet Metall human capital in terms of education and experience

Total amount of employees: 69

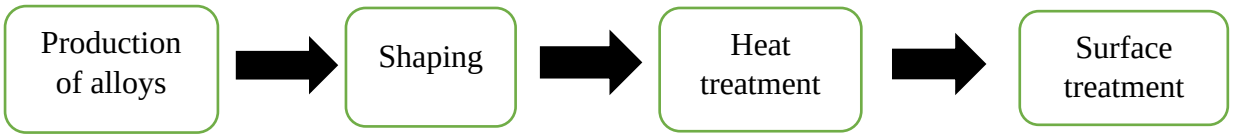
Education is measured in terms of fundamental (9 classes), secondary (12 classes) and higher (12 classes + higher education institution)

| Employee | Education | Experience (in years) |
|---|---|---|
| 1 | higher | 15 |
| 2 | secondary | 12 |
| 3 | secondary | 8 |
| 4 | secondary | 4 |
| 5 | higher | 11 |
| 6 | secondary | 15 |
| 7 | secondary | 3 |
| 8 | secondary | 18 |
| 9 | secondary | 9 |
| 10 | higher | 13 |
| 11 | higher | 7 |
| 12 | secondary | 3 |
| 13 | secondary | 11 |
| 14 | fundamental | 1 |
| 15 | secondary | 13 |
| 16 | higher | 10 |
| 17 | higher | 14 |
| 18 | secondary | 1 |
| 19 | secondary | 14 |
| 20 | secondary | 9 |
| 21 | secondary | 2 |
| 22 | secondary | 6 |
| 23 | fundamental | 15 |
| 24 | secondary | 4 |
| 25 | higher | 5 |
| 26 | secondary | 3 |
| 27 | higher | 4 |
| 28 | higher | 1 |

| | | |
|---|---|---|
| 29 | higher | 18 |
| 30 | secondary | 17 |
| 31 | secondary | 4 |
| 32 | fundamental | 0 |
| 33 | higher | 14 |
| 34 | higher | 7 |
| 35 | secondary | 5 |
| 36 | secondary | 19 |
| 37 | higher | 2 |
| 38 | secondary | 5 |
| 39 | higher | 15 |
| 40 | higher | 7 |
| 41 | secondary | 17 |
| 42 | secondary | 4 |
| 43 | secondary | 11 |
| 44 | higher | 16 |
| 45 | higher | 2 |
| 46 | fundamental | 1 |
| 47 | higher | 8 |
| 48 | secondary | 11 |
| 49 | secondary | 14 |
| 50 | higher | 4 |
| 51 | higher | 19 |
| 52 | secondary | 3 |
| 53 | secondary | 3 |
| 54 | secondary | 4 |
| 55 | secondary | 12 |
| 56 | secondary | 6 |
| 57 | secondary | 6 |
| 58 | higher | 4 |
| 59 | secondary | 11 |
| 60 | secondary | 17 |
| 61 | secondary | 3 |
| 62 | secondary | 13 |
| 63 | higher | 2 |
| 64 | secondary | 3 |
| 65 | secondary | 16 |
| 66 | secondary | 9 |
| 67 | secondary | 7 |
| 68 | secondary | 12 |
| 69 | higher | 10 |

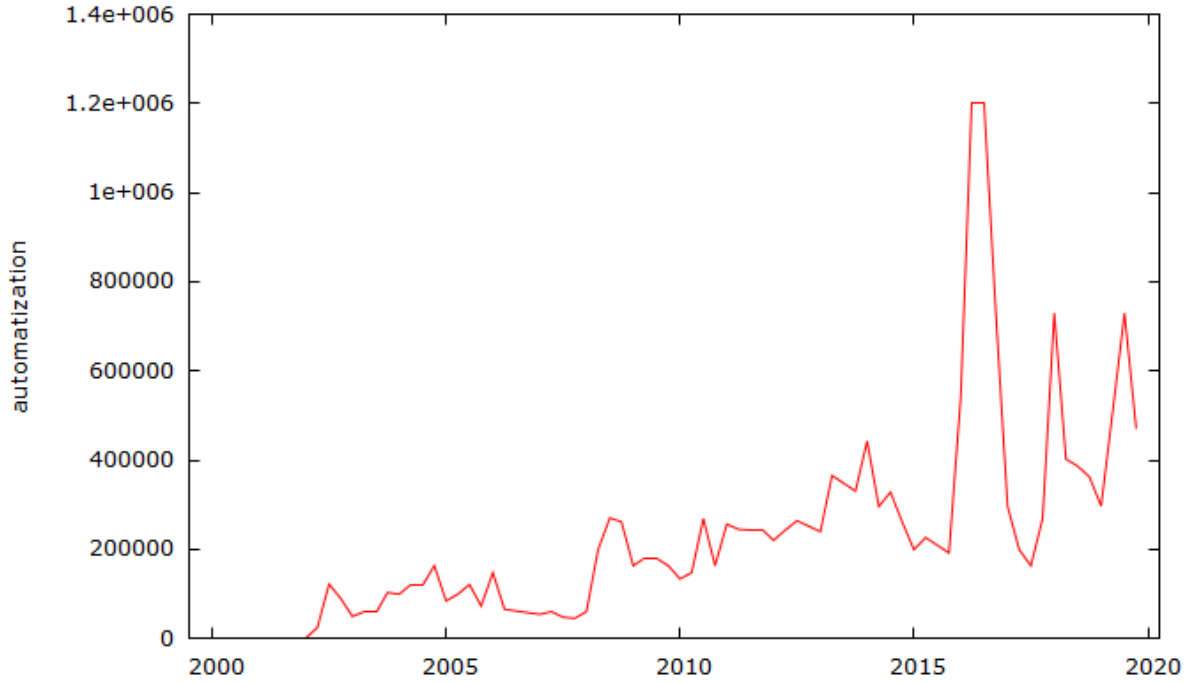
Source: internal information, OÜ Falkonet Metall archives

## Appendix 2. OÜ Falkonet Metall metal furniture production process



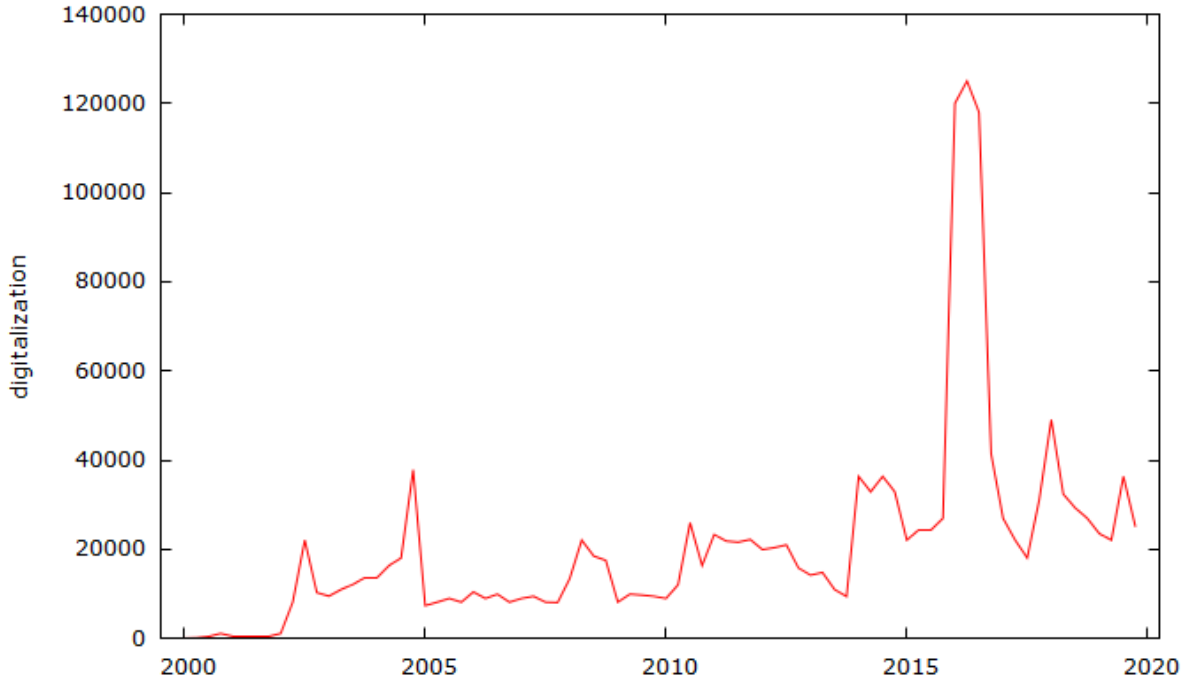

Source: internal information of OÜ Falkonet Metall

## Appendix 3. OÜ Falkonet Metall acquisition costs of automated machines (depreciation included)



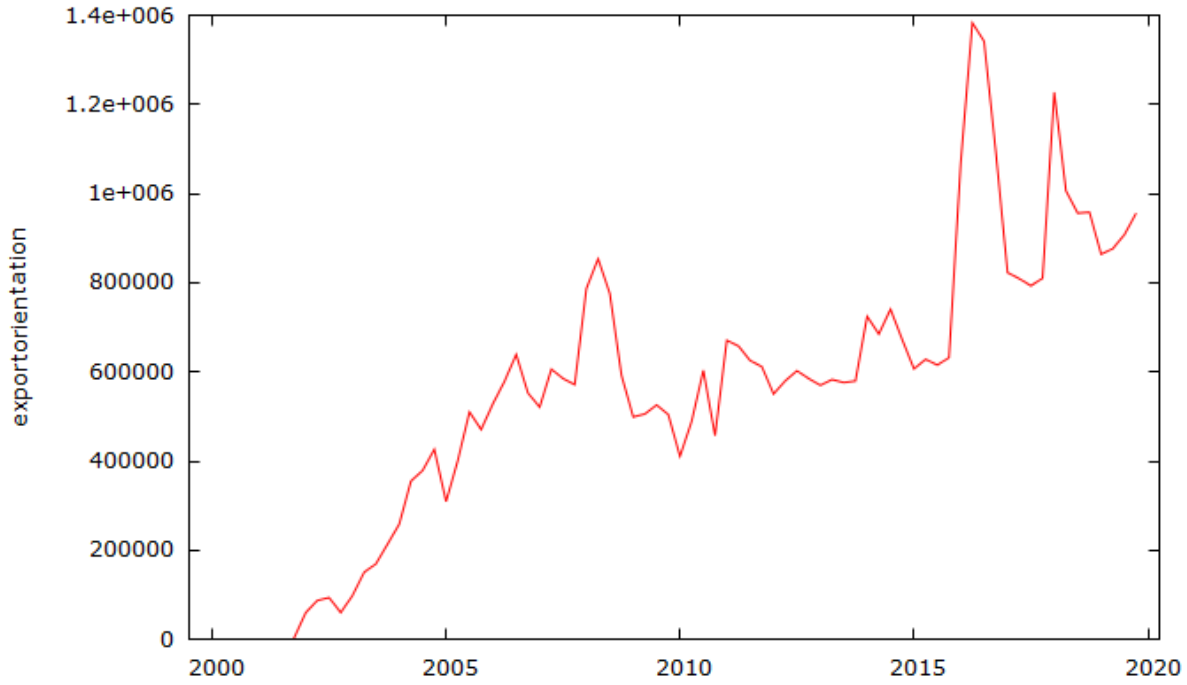

Source: author's calculations in Gretl software

## Appendix 4: OÜ Falkonet Metall acquisition costs of information technology systems (depreciation adjusted)



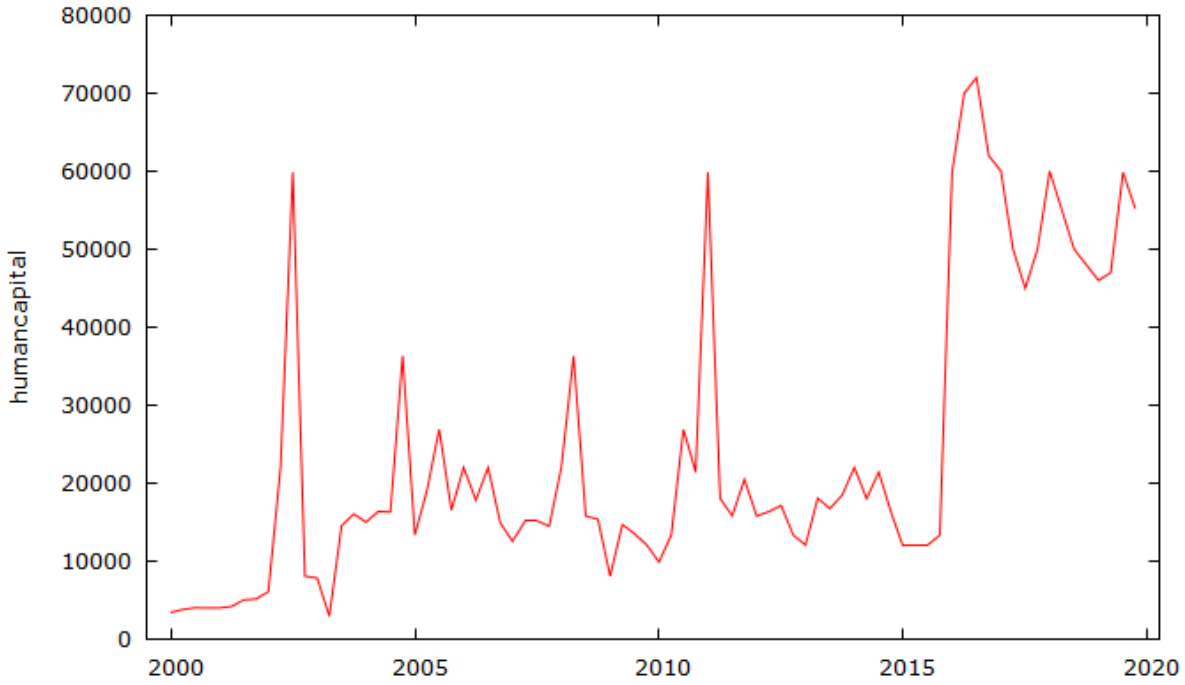

Source: author's calculations in Gretl software

## Appendix 5. OÜ Falkonet Metall export orientation



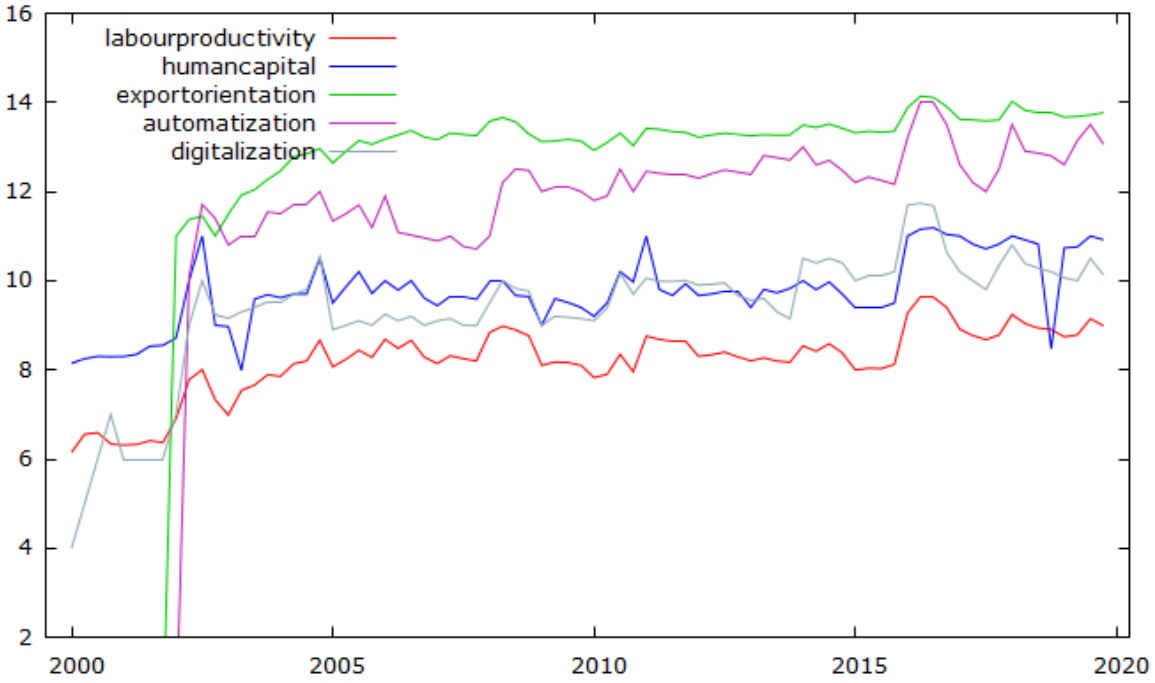

Source: author's calculations in Gretl software

## Appendix 6. OÜ Falkonet Metall human capital intensity




Source: author's calculations in Gretl software

## Appendix 7. The development of investigated indicators in observed period




Source: author's calculations in Gretl software

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