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Capital-Labor Substitution and Economic Efficiency in the Context of Industry 4.0

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Abstract: The aim of the paper is to provide an insight into the area of substitution of human labor by the capital of the manufacturing sector. First, the labor market in the Czech Republic is described and then an economic analysis of the process of replacing human labor with a robot is performed. This analysis will be reflected in the Stella Professional tool, which enables dynamic modeling of economic systems using visual diagrams. At the same time, this tool allows mathematical calculations and simulations that will be created fifteen years in advance. These simulations are used to calculate the economic return on investment in the robotization of production plants. Companies can enter their own input values in the created model and the tool calculates the payback period of the investment project and identifies the time frame when the investment is most appropriate to make.

Keywords: Industry 4.0; substitution; labor market; robotics; return on investment

JEL Classification: E24; O14; D61

1. Introduction

Unemployment is a key macroeconomic indicator. During the Covid-19 pandemic, unemployment was forecast to increase. However, the increase was minimal due to government measures and the unemployment rate remained below the natural unemployment rate. The demand for labor was higher than the labor supply in the Czech Republic. Companies are being forced to raise wages or offer more benefits to recruit new employees. The second way is automation and robotization of production. And it is this unfavorable situation on the labor market that can lead to a higher substitution of labor by capital and a faster onset of Industry 4.0.

The importance of the elasticity of substitution between capital and labor has been studied in many areas of economics, but this parameter has not received sufficient attention with regard to the assessment of economic growth (Mallick, 2012). The study (Gechert et al., 2021) states that the effectiveness of interest rate changes in managing inflation doubles when the elasticity between capital and labor is assumed to be lower than in the literature of 0.9. This elasticity has significant implications for monetary policy and political decision-making.

The model (Alvarez-Cuadrado et al., 2017) confirmed that as the aggregate capital-labor ratio and the wage-rent ratio increase, the sector with higher factor substitution elasticity - the more flexible sector - is in a better position to replace progressively more expensive input-labor - and gradually cheaper-capital - compared to the less flexible sector. As a result, differences in the sectoral elasticity of substitution between capital and labor evokes a process of structural change. In their article, they confirmed that there is direct econometric evidence that the

elasticity of substitution varies between sectors. And also that there is evidence that the capital-labor ratio is growing at different rates in different sectors. And third, they confirmed that factor income shares have evolved differently across sectors.

Sectoral shares of labor income (capital-labor-energy-materials) in the US have been examined by a number of studies (Alvarez-Cuadrado et al., 2017; Zuleta & Young, 2013).

A US agricultural study (Hamilton et al., 2021) points to problems, suggesting that wage-setting farmers have an incentive to "over-mechanize" or employ more than a level of capital that minimizes costs when capital and labor are substitutes but "under-mechanize", when labor and capital are technical additions.

Current technologies have made it possible to generate new products and services, both of which have led to significant transformations of personal and professional life with an emphasis on interaction between machines and people (Sima et al., 2020).

The potential effects of investing in new technologies include four dimensions: costs, benefits (business impacts), flexibility (future options created by the investment) and risk (uncertainty) (Botchkarev & Andru, 2011).

At present, fiscal (Král, 2017) and monetary policies are also important for the implementation of the installation, for example, the revaluation of the domestic currency exchange rate has implications for the substitution of labor by capital (Mačí, 2020).

Tay et al. (2018) presented Industry 4.0 as a global change for every part of society 's digitization and automation, as well as through manufacturing processes (Sima et al., 2020). Unemployment can be a negative phenomenon in Industry 4.0. There is a directly proportional relationship between the degree of production automation and the unemployment rate: the higher the degree of production automation, the higher the unemployment rate (Leonhard, 2017). As a result of machine automation, the creativity of human capital and its loss from the production process may decrease. However, new jobs will be created and there may be better environmental protection, for example by lower energy consumption of modern machinery and equipment (Sima et al., 2020). In this paper, Industry 4.0 is understood as a way to substitute labor by capital (Hedvičáková & Král, 2021).

2. Methodology

The article uses primary and secondary data. Primary data are obtained from a company operating in the field of plastic injection. For competitive reasons, the company did not wish to provide further information. Based on the data provided, a model will be created to analyze whether and when it pays to invest in new technologies and replace labor with capital. This information is supplemented by data from interviews with the country manager of the robot manufacturer KUKA, which took place in June 2021. Data from public databases such as the Czech Statistical Office, Eurostat, the Ministry of Labor and Social Affairs and the Ministry of Industry and Trade were used for labor market analysis. Czech Republic. Furthermore, information was obtained from worldwide professional conferences and workshops. The information is also supplemented by professional publications and articles from impacted journals.

The aim of the article is an economic analysis of the process of substitution human labor with a robot. This analysis will be displayed using Stella Professional software, which allows dynamic modeling of economic systems using visual diagrams. At the same time, this software will be used to allow mathematical calculations and simulations for fifteen years in advance. Based on this, the economic return on investment in the robotization of production facilities will be calculated. At the same time, calculations of payback time and net present value in the model are performed.

The proposed model will serve the private corporate sector to calculate the payback period of their investment project and the benefit will be the identification of the time frame when to implement this investment. Companies will be able to choose their input values and adjust them according to their needs.

Every company is interested in the decision to make an investment: how long it will take for the investment to return and whether the investments made in the substitution are spent efficiently. Several basic calculations are used for this. The concept of investment assumes the purchase of automated production technologies based on 6-axis robots with accessories such as various grippers, control camera systems, intelligent conveyors, sophisticated sensors, etc. Payback period and Net present value are the key economic indicators evaluating the return on investment in the company.

The NPV approach probably the most popular and most sophisticated economic valuation technique is the NPV approach. It consists in discounting all future cash flows (both in- and out-flow) resulting from the innovation project with a given discount rate and then summing them together (see Equation 1). The merit of innovation is measured considering its contribution to the creation of economic value out of the investment needed (Žižlavský, 2014).

Net Present Value (NPV) formula (Žižlavský, 2014):

$$NPV = \sum_{t=1}^{n} \frac{NCFt}{(1+i)^t} \tag{1}$$

where:

NCF_t = net cash flow generated by innovation project in year t;

i = Discount rate or return that could be earned in alternative investments;

t = Number of timer periods.

The formula was further modified for the needs of the model:

$$NPV = \sum (Savings * (1+i)^{-n}) - Investment \tag{2}$$

The second widely used tool for evaluating investment efficiency is Return on Investment (ROI). ROI is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio (Botchkarev & Andru, 2011).

The return on investment formula (Botchkarev & Andru, 2011)

$$ROI = \frac{Gain\ from\ Investment\ -\ Cost\ of\ Investment}{Cost\ of\ Investment} \tag{3}$$

Because not all the data in the calculation formula are used in the model, it is not possible to determine the amount of profit. This quantity will be replaced by savings and it will be assumed that the savings will increase the level of profit. Profit will then be treated as a differential. Depreciation will be worked on in more complex models. Depreciation will not be considered for the first models.

The return on investment formula for model:

$$Payback\ period = \frac{Investment}{Saving} \tag{4}$$

Discounted payback period formula:

$$Discounted\ payback\ period = \frac{Investment}{(\sum(Savings + Depreciation) * (1+i)^{-n})/5} \tag{5}$$

The formula considers 5-year depreciation periods of tangible fixed assets.

All of the above formulas have multiple definitions and modified calculation formulas (Botchkarev & Andru, 2011; Hedvičáková & Král, 2019; Žižlavský, 2014)

3. Results

3.1. Actual Situation on Labor Market in the Czech Republic

The labor market in the Czech Republic has one of the lowest unemployment rates in the European Union in recent years. Unemployment rates have been lower than the natural unemployment rate in recent years. In 2021, the general unemployment rate was 3.86% (see Figure 1) in the Czech Republic. According to Eurostat, the unemployment rate in the EU-27 was 7% and in the Czech Republic 2.8%. The Czech Republic has the lowest unemployment rate of all EU countries, the second country with the lowest unemployment rate is Poland with 3.4% (Eurostat, 2022).

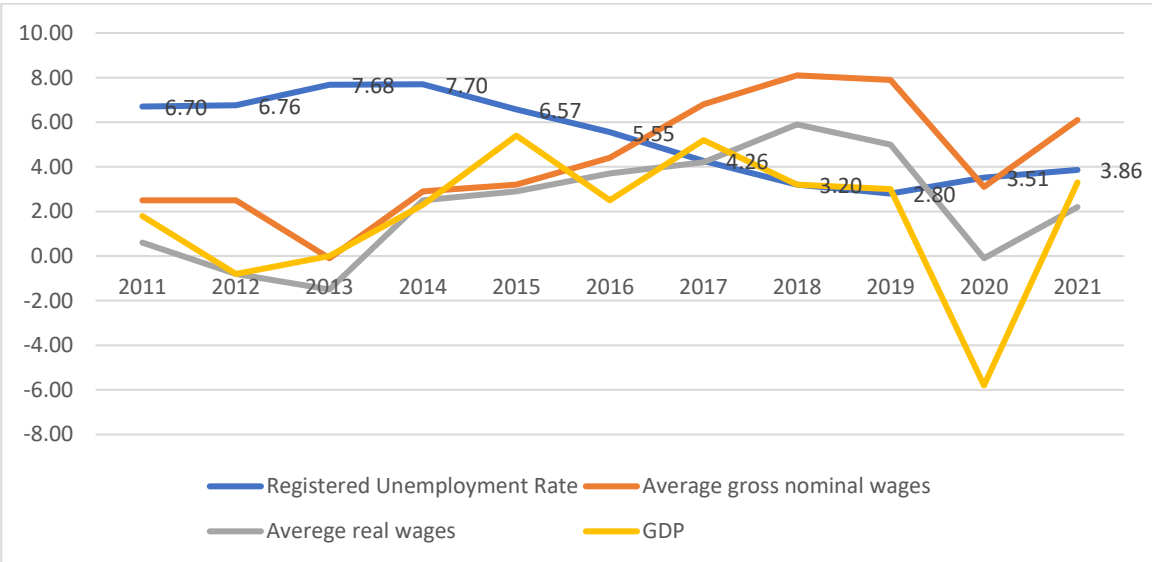

Figure 1. Key macroeconomic indicators in % (Czech Statistical Office, 2022)

Companies cannot find a sufficient number of qualified employees because labor demand is higher than labor supply. Companies have orders, but they solve problems: "How to produce?" One way is to increase wage rates and company benefits, and the other way is to invest in robotics and production automation. Companies are starting to prefer the second way, because in addition to increasing production capacity, it brings production 360 days a year, without increased wage costs for work on holidays or night shifts. Quarantine and sickness benefits also do not have to be addressed. New predictions of rising labor costs are forcing companies to look for production optimization and savings. In 2022, the rate of inflation will also rise significantly, which will increase the pressure on nominal wage growth as real wages fall. There is also a significant increase in electricity, gas and oil prices. New machines are usually more economical and environmentally friendly. Another positive aspect of production robotization is the 100% production quality, because modern machines can analyze defective pieces and eliminate them from production.

For the above economic and other reasons, companies choose to substitute labor for capital. For this reason, a substitution model has been proposed that calculates whether and when capital investment is economically efficient.

3.2. Capital-Labor Sustitution Model

When evaluating the substitution of labor by capital, it must consider the differential costs that are present in this substitution. It is not efficient to evaluate all the costs of the calculation formula and it would only complicate the evaluation mechanism. The notion of relevant substitution costs will be introduced. These costs change when labor is replaced by capital. The following relevant substitution costs were identified. Labor costs, energy costs, production quality costs. On the other hand, the investment expenditures of substitution (subsequently the costs in the form of depreciation) are included in the evaluation. The production function is considered both fixed and variable (Hedvičáková, 2021).

Based on the identified relevant costs, several models were created in the economical Stella Professional programming environment. Figure 2 presents the basic simplest model, in which only investment expenditures and labor costs are considered.

In subsequent articles, this simple model was further developed into a more complex model. Other aspects have been added, such as energy costs and low-quality production costs. The possibility of production growth due to higher production efficiency of robotic automation was also accepted.

The result of the input data of this model is a table where each row represents 1 year in which the investment can be started. The investment can be made, for example, in year 1, or in year 10 or 15. The input variables are constantly recalculated and provide information on whether it is worthwhile to realize the investment at a given time or to postpone it.

In total, the model is calculated for 15 years. In each year, input variables are calculated with a possible increase or decrease in price. It is clear from the table that, for example, the input variable the price of the work of replaced employees with an annual growth of 6% will change from the input value of CZK 782,006 to CZK 1,720,000 at the end of the modeled period during the 15-year period (see Figure 2). Return on the number of years is calculated

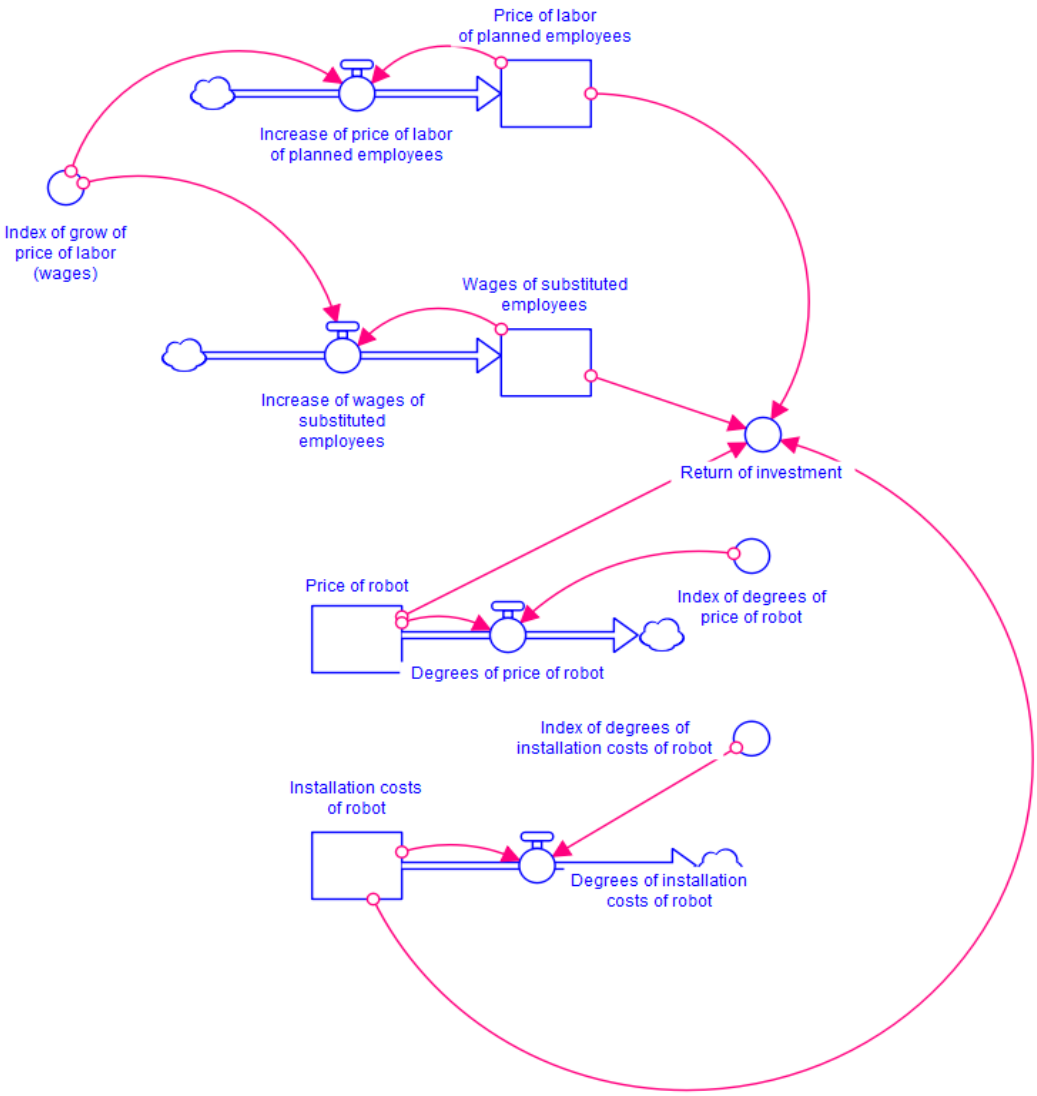

Figure 2. Labor-capital substitution model (own processing in Stella Proffesional)

	Wages of substituted employees	Price of robot	Installation costs of robot	Return of investment
1	782k	800k	1,5M	2,94
2	829k	800k	1,5M	2,77
3	877k	800k	1,5M	2,62
4	928k	800k	1,5M	2,48
5	981k	800k	1,5M	2,34
6	1,04M	800k	1,5M	2,22
7	1,1M	800k	1,5M	2,09
8	1,16M	800k	1,5M	1,98
9	1,23M	800k	1,5M	1,87
10	1,3M	800k	1,5M	1,77
11	1,38M	800k	1,5M	1,67
12	1,46M	800k	1,5M	1,58
13	1,54M	800k	1,5M	1,49
14	1,63M	800k	1,5M	1,41
Final	1,72M	800k	1,5M	1,33

Figure 3. Development of return on investment over fifteen years (own processing in Stella Professional)

for each year. The return value varies depending on the values of the input variables in a given year and expresses the length of the return in years for the values of the modeled input variables valid in a given year. From the above table it is clear that the growth of labor costs combined with the stagnation of costs for new technologies means that the payback period of potential investment will shorten in the coming years.

The following Figures 2 and 3 show the return of investment. If the investment is made in the current year, the return of investment (difference between wage and robotic workplace expenses) will be less than 3 years. If the investment were made in 5 years, it's payback period would already be 2.34 years, due to rising labor costs and the persistence of costs for the robotic workplace. If the investment were realized in the fifteenth year, the payback period of the investment would be 1.33 years.

Figure 3 (right graph) also shows that the wages of the employees are rising over time, but the price of robots is falling over time. This decrease in the price of robots is caused by a significant increase in the number of robots sold and a reduction in the cost of production due to new technologies.

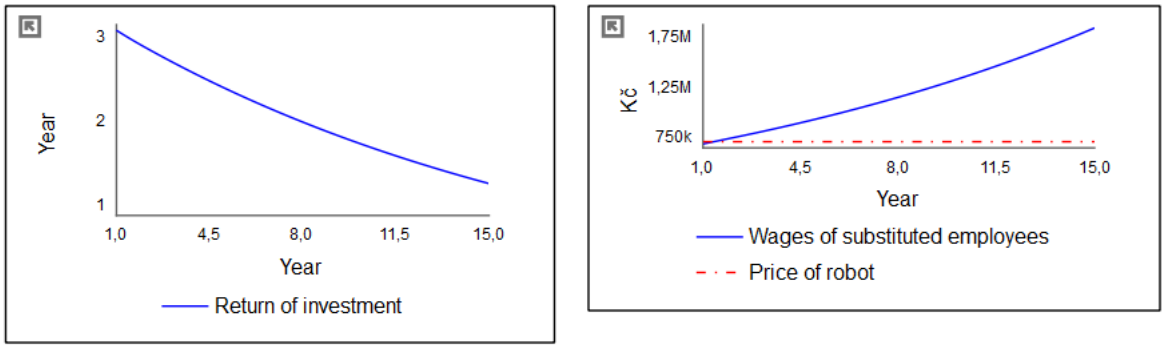

Figure 3. Development of labor costs (wages) and return on investment over fifteen years (own processing in Stella Professional)

4. Discussion

The paper "Capital-Labor Substitution and Economic Efficiency in Context Industry 4.0" is based on the current situation in the European market. The key questions are: To substitute a human labor with a robot or not? How effective and repayable is this compensation? Aren't these just marketing games? The paper provided a new perspective on the economic model of substituting labor with capital. In addition, a mathematical and economic view of substitution has been developed and a parameterizable tool has been created to enable companies to support them in deciding whether or not to invest in substitution. However, it should be noted that marketing and strategic considerations are also part of decision-making, and a pure mathematical calculation of return and net present value cannot be isolated in decision-making.

The model has been validated in several companies and modified to the requirements of company managers. In future research, it would be appropriate to verify the model on multiple types of companies and incorporate the acquired into other models.

5. Conclusions

In all phases of investment projects, from the first idea to the final implementation, it is therefore necessary to assess efficiency according to financial and non-financial criteria. The results of the research will help solve the problem of empirical evaluation of the importance of individual variables in determining future earnings, and will propose measures to improve the evaluation of investment performance using dynamic models and mathematical calculations with predictions of development for the next fifteen years (Žižlavský, 2014). The Czech Republic lacks such a user-friendly tool and would be very beneficial for companies to evaluate the return on investment.

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