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ECONOMIC IMPACTS OF TECHNIQUE SUBSTITUTION IN CHEMISTRY DUE TO INDUSTRY 4.0

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Abstracts
The paper analyzes corporate economic effects caused by the substitution of labour by a technique. This kind of substitution is the main phenomenon of Industry 4.0. There is a lack of evidence that the economic benefits of Industry 4.0 outweigh the costs incurred. The paper proves if the initiative Industry 4.0 has positive impacts on corporate performance and if the opposite substitution (increasing importance of labor) does not lead to negative consequences on business results. Financial ratios focused on partial costs are employed to analyse traditional business financial data. The computed cost structure and development are summarized and evaluated by descriptive statistics and the effects of substitution are visualized applying the regression analysis. The chemical companies present a less significant effect of coming Industry 4.0 on the corporate performance than the logistic companies. The general development of the chemical industry was opposite and increasing importance of labour led to the lower level of performance in many cases. Such results could indicate the warnings of late implementation of Industry 4.0 in companies.

Keywords: *business performance, chemistry industry, cost structure, Czech Republic, Industry 4.0, operational costs, substitution of labour by a technique.*

JEL Codes: *M21, O33, L65.*

Introduction

It is expected that Industry 4.0 would trigger significant changes in technologies, businesses or society (Čámská, Klečka, 2020) because of revolutionary technological shifts (Rüβmann et al., 2015). Technological changes addressed in the initiative Industry 4.0 could be a good response to the latest or current conditions. The prevailing situation on the labor market could be mentioned when many European companies face a lack of manpower in a number of field and professions (Poór et al., 2021) as well as accompanied by the aging population in the developed countries globally (Oh et al. 2011). Second, the pandemic COVID-19 represents unexpected development disruption which could have negative as well positive impact on the implementation of Industry 4.0 in practice. COVID-19 created a challenging environment as companies struggled with a lack of available healthy employees, or they were forced to close their corporate plants due to safety health regulations. This could be the trigger for the implementation of new technological solutions that will reduce the share of human labor and will respond to challenges posed by COVID-19. Contrariwise, it could be discussed that companies exposed to existential difficulties are forced to solve different issues than the implementation of Industry 4.0 in practice. Investment activities are postponed because of crisis moments (González, 2016; Fakos et al., 2022).

Technological shifts related to Industry 4.0 lead generally to replacement of human labour (Rotman et al., 2013) by modern machines (Barreto et al., 2017) and relate to enormous cash expenditures (Zühlke et al., 2013; Jereb, 2017) mostly into fixed tangible and intangible assets (Bettenhausen et al., 2010). It is emphasized e.g. by Mařík et al. (2016) that these investment activities should mitigate the risk of losing business competitive advantage. The loss of competitiveness is mostly emphasized in the case of small and medium business which might not catch the new development phase in time (Sommer, 2015). On contrary, many investments do not reach their expectations and can cause business existential difficulties. According to Kiel et al. (2017), discussion focused on economic effects of Industry 4.0 is still in its fancy and existing research has focused primarily on technical and technological issues. This can also be observed in connection with COVID-19, when areas such as medical equipment (Javaid et al., 2020), logistic systems (Buranasing et al., 2021), and data analyses (Acioli et al., 2021) are detected where Industry 4.0 could help. Economic impacts stay just only verbally indicated. Research papers addressing quantitative estimations and verifications of consequences of the technological shifts related to Industry 4.0 on business performance, employment, and productivity seem to be still rare how it is described in the Section Literature review.

This paper should contribute to closing the gap in the area of lack of research works focused on the influence of Industry 4.0 on economic variables and overall business performance. The special attention should be paid to the question if the economic benefits of Industry 4.0 outweigh the costs incurred. The purpose is to conduct analysis of business financial data with an emphasis on the replacement of human labour by technique and to prove if these technological shifts have or do not have positive impact on the overall business performance measured by corporate profitability. The paper's objective is to analyze the cost structure, describe its development with an emphasis on shifts caused by the initiative Industry 4.0, and detect the impacts on profitability.

Methodological approach based on the analytical apparatus using traditional business financial data is explained in detail in Section Research methods. Financial ratios focused on partial costs are employed to analyse the cost structure and its development with an emphasis on personnel costs and depreciation and amortization. Received results of employed indicators are evaluated by descriptive statistics and the effects of substitution are visualized applying the regression analysis. This apparatus is applied to Czech companies belonging to chemistry industry. Data sample was extracted from the database Albertina and its final size is 564 units.

The research should provide the verification of consequences of the technological shifts related to Industry 4.0 on business performance. Such conclusion is worthy for either the science or practice and especially for policy makers and government preparing different projects and programs supporting the implementation of Industry 4.0 in practice.

Literature review

The global phenomenon is not presented worldwide by the term Industry 4.0 as explained by Lasi et al. (2014) because it was developed in German speaking countries, from where it has spread only to related countries, and therefore an alternative term applied globally could be the expression of smart industry. More recently, the term Industry 5.0 (Rockwellaumation) has also appeared, which does not have a very clear definition and represents a certain vision of the return of human creativity to the production process. The original term Industry 4.0 can be understood as the fourth independent industrial revolution (Mařík et al., 2016) but the innovations referred to as Industry 5.0 cannot be a symbol for another independent development stage because it only serves as a refinement and update of the current Industry 4.0. Similar discrepancy could be also detected in connection to Logistics 4.0. Some authors such as Cyplik et al. (2019) and Maslaric et al. (2016) distinguish between Industry 4.0 and Logistics 4.0. Logistics 4.0 is just a narrow concept of Industry 4.0 which should be dedicated to more complex activities (Krykavsky et al., 2019) not covering only production but also procurement, design, internal and external logistics, sales, and after-sales services. Prevailing thinking assumes that Industry 4.0 refers only to the production in a narrow sense which excludes additional and supporting activities already specified.

Technological changes addressed in the initiative Industry 4.0 contain specifically Autonomous robots, Simulation, Horizontal and vertical system integration, The Industrial Internet of Things, Cybersecurity, The cloud, Additive Manufacturing, Augmented Reality, Big data and analytics (Rüβmann et al., 2015). These innovations of Industry 4.0 could be mainly counted in the enormous cash expenditures into tangible and intangible fixed assets in companies (Zühlke et al., 2013). Increased investment in fixed assets would cause partial displacement and reduction of human labor (Rotmann et al., 2013) which would change the labour market (Kergroach, 2017) and lead to wages inequalities (Moenning et al., 2019).

It seems difficult to imagine that significant changes in the production processes would appear in chemistry as far as their purely technical side is concerned. However, the innovations of Industry 4.0 can introduce deep socio-technical shifts gradually over years to decades according to Malanowski, Brandt (2014) and Technický týdeník (2014). The specific recent examples of the Industry 4.0 application in the chemical industry are innovations using the improvement of interconnection and digitization of the entire value chain (Palíšek, 2018). Palíšek (2018) mainly mentions the use of Big Data analysis, strengthening cyber security or the concept of a digital twin.

It is assumed that the Industry 4.0 concept will probably have a smaller impact on the chemical industry than on a number of other fields, such as the production of machines and machinery or the automotive industry (Malanowski, Brandt, 2014). However, in order to maintain competitiveness (Sommer, 2015), the requirements for reliability, speed and flexibility of the production and the entire logistics chain will also increase for a number of other fields - including the chemical industry.

Some industries are further because of frequently discussed autonomous robots (Erdei et al., 2018; Gubán, Kovács, 2017) or impacts on internal as well external logistics in the form of RFID (Radio Frequency Identification), RTSL (Real Time Locating System), Cyber-Physical Systems, IoT (Internet of Things and Services), and Big Data (Cyplik et al., 2019). Contrariwise, even for the automotive industry, it has already been observed that the implementation of Industry 4.0 is very uneven among small and medium-sized enterprises (Arcidiacono et al., 2019).

The research emphasizing economic discussion of the effects of the Industry 4.0 seems still to be in fancy (Kiel et al., 2017) although more and more companies have already introduced new technologies representing the Industry 4.0 innovations (Romberg, 2016). Pioneering general economic estimates highly cited could be found in Rüβmann et al. (2015) and McKinsey Global Institute (2015). Authors mostly focus on the description of possible technological shifts and they only indicate the areas of potential impact. Müller et al. (2018) predicts the positive effect of Industry 4.0 on Supply Chain in the form of flexibility, data usability, decreasing documentation efforts, costs savings, traceability or decreasing of incorrect delivery. Acimovic et al. (2019) states that new technologies enable improvement in manufacturing, delivering time, cost effectiveness which would lead to the greater profit. Other research papers have been pointed out in Introduction related to the challenges of COVID-19. Such descriptions are general and they do not provide any quantifications proving their statements. Unfortunately, quantitative research is still rare in the area of economic impacts of the Industry 4.0 innovations.

Some economic proofs based on real data verification could be found in Dalenogare et al. (2018) applying regression analysis and proving that some emerging technologies are more promising in the case of the Brazilian enterprises, in Brendel (2018) whose effort was to find an evidence supporting that the economic benefits of Industry 4.0 outweigh the costs incurred, in Erdei et al. (2018) emphasizing the impact of autonomous industrial robots on productivity, employment, and value added, and in Čámská, Klečka (2020) analyzing the substitution of production factors in the logistic companies in the Czech Republic.

Economic consequences of aforementioned described technological shifts influencing also workforce, working conditions, and requirements must be solved not only by enterprises themselves but also by unions and by policy makers for support of innovations and research (Mařík et al., 2016; Technický týdeník, 2014). New technologies related to Industry 4.0 seem to show the potential to lead businesses to higher profits, which will be important to maintain and strengthen their competitiveness. Such statements need research and evidence to support the adoption of Industry 4.0 by enterprises and by policy makers. The following part will introduce the methodology how to analyze the economic effects of substitution of production factors and to receive the needed evidence.

Research methods

The classic ratios of financial analysis are too general and would not be able to fulfil the paper's objective. The ratios have to be redefined to analyse the considered kind of substitution. The measures applied in this study combine the classic financial ratios and the ratios of partial cost. Selected cost items have to be subordinated to the needs of reflection included in the paper's objective. The factor of human labour is presented by the cost item personnel expenses consisting of wages, salaries, and obligatory healthy and social insurance paid by employers. The factor of investments into fixed intangible and tangible assets is expressed in the area of costs by depreciation and amortization of fixed assets (in income statement referred as permanent value adjustments). Depreciation and amortization allow to allocate the purchasing price of fixed assets over their useful time life into expenses. It should be noted that the business growth has an impact on revenues as well as expenses which both increase. The increase of these indicators is absolute but when the company performs appropriately the growth of expenses should be relatively smaller to the revenue growth. Described relationship of the absolute and relative growth will be reflected in the paper by the application of ratio indicators to which the following text is dedicated.

The paper's analysis works with two subsidiary indicators and two explanatory ratios. The carried out research is based on the same methodology as explained in Klečka, Čámská (2020) and applied in Čámská, Klečka (2020). The values of items included in indicators are extracted from the income statement in 2015 (base period) and 2018 (following period). First subsidiary ratio indicated as A expresses the absolute change in depreciation and amortization over sales. The ratio A has the potential to express partial changes in the expenses over sales (generally over revenues). If the indicator value is positive the company has invested into fixed assets more than it is the business increase in revenues. This cost growth corresponds only to the increase on depreciation and amortization which states the simplified substitution of production factors. The impact on profitability without an input replacement (only the assets growth) would be following. If there is a partial increase in expenses over sales it will cause a partial decrease on the profitability of sales. It is assumed that the technique replaces the human labour therefore it is necessary to quantify impacts of changes in the production of human labour.

$$A = \frac{DaA_{2018}}{Sales_{2018}} - \frac{DaA_{2015}}{Sales_{2015}} \qquad (1)$$

Where

DaA – depreciation and amortization (in CZK);

Sales – total revenues from selling finished products, resold goods and services (in CZK);

2015 – base period;

2018 – following period.

The indicator B expresses the absolute change in personnel expenses over sales and it also serves as the subsidiary indicator. The indicator's potential is to demonstrate a partial decrease in the costs over sales, and thus a partial increase on the profitability of sales caused by the declined consumption of production factors substituted by others. Negative value of the indicator means that the enterprise has spent relatively less on wages and salaries than it is the business increase in revenues. It should be reminded that relative values are taken into

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consideration because the absolute value of personnel costs itself increases dues to the business growth.

$$B = \frac{PersC_{2018}}{Sales_{2018}} - \frac{PersC_{2015}}{Sales_{2015}} \quad (2)$$

Where

PersC – personnel costs (in CZK).

The knowledge of ratios A and B allows to construct the ratios C and D representing main indicators. The aim of the ratio C is to express the direction and size of labour replacement by technique. Its construction is based on previous subsidiary indicators A and B whose difference is quantified. It compares the change of shares of the corresponding cost kinds in the value structure of production. The replacement of these production factors is expressed in financial terms. It shows how personnel costs are substituted by depreciation and amortization over sales. The interpretation of results follows the logic that the positive value means that labour is replaced by technique which is the typical substitution in the case of Industry 4.0 innovations. Higher value indicates higher extent of the substitution. The result of 0 would point no replacement took place. Finally, the negative value shows the opposite direction of substitution in the analysed company. Such situation would be interpreted that the technology has been replaced by the human labour which is not representative for the Industry 4.0 innovations. It should be noted that cost variables serve only as the simplified measure expressing the consequences of the analysed substitution.

$$C = \left(\frac{DaA_{2018}}{Sales_{2018}} - \frac{PersC_{2018}}{Sales_{2018}}\right) - \left(\frac{DaA_{2015}}{Sales_{2015}} - \frac{PersC_{2015}}{Sales_{2015}}\right) = A - B \quad (3)$$

The main corporate incentive for innovations is generally the improved performance and fulfillment of enterprise objectives which could be represented by the enterprise value in the long-term and by the enterprise profit in the short-term. The indicator D has the potential to present the partial change in sales profitability caused by the substitution of production factors. The final ratio value shows a positive, none, or negative change in the sales profitability due to the monitored input replacement.

$$D = (-1) \times \left(\frac{DaA_{2018} + PersC_{2018}}{Sales_{2018}} - \frac{DaA_{2015} + PersC_{2015}}{Sales_{2015}}\right) \quad (4)$$

The received results of aforementioned explained indicators will be presented in tables based on descriptive statistics such as mean, median, quartiles, and standard deviation. The key result of the conducted research should be the dependency between the discussed inputs' substitution and sales profitability (dependency between indicators C and D). This dependency will be displayed graphically because the visualization is able to bring the results closer to a wider range of readers. Regression analysis employed proves the dependency not only from the visual point of view but also from the quantified point of view.

The paper objective has to be tested on the real observations representing companies. The carried out analysis covers the time period 2015-2018. The choice of time period is discussed in the part devoted to Discussion. The data sample employed herein contains companies belonging to the chemical industry. Despite perceived homogeneity of the chemical industry it consists of three industry branches according to the classification CZ-NACE, specifically CZ-NACE 20 Manufacture of chemicals and chemical products, CZ-NACE 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations, and CZ-NACE 22 Manufacture of rubber and plastic products. The data observations were extracted from the prepaid Czech corporate database Albertina (originally operated by Bisnode renamed to Dun & Bradstreet), accomplishing the belonging to the selected industry sector, having the form of business corporation, and reaching the minimal annual sales of 10 million CZK. The reasons of selection criteria are following. The belonging to the specific sector is based on potential differences of the implementation of Industry 4.0 (Malanowski, Brandt, 2014). The form of business corporation is to ensure the use of financial accounting. The last criterion reflects the size condition because of slower and more limited access to the innovation of Industry 4.0 (Arcidiacono et al., 2019; Sommer, 2015).

The size of the final data sample is influenced by the availability of financial statements and therefore only companies fulfilling disclosure are included in the sample whose structure is displayed in Table 1. There are 564 companies in total of which almost 25% belong to CZ-NACE 20, 5% belong to CZ-NACE 21 and the highest share of almost 70% is occupied by CZ-NACE 22. When the sample structure is analysed according to the value of annual sales different decomposition is received. The highest share is connected with CZ-NACE 20 (47.35%), followed by CZ-NACE 22 (46.46%) and concluded by CZ-NACE 21 (6.19%).

Table 1. Structure of the data sample

	Number of Companies	Share on Total Sample	Total Sales in million CZK*	Share on Total Sample
CZ-NACE 20	140	24.82%	245,240	47.35%
CZ-NACE 21	30	5.32%	32,084	6.19%
CZ-NACE 22	394	69.86%	240,632	46.46%
CZ-NACE 20-22	564	100.00%	517,956	100.00%

*1 EUR = 25.35 CZK as of 23 February 2024.

Research results and discussion

This part is devoted to received results which will be presented in tables and figures and interpreted. The first indicator, whose descriptive statistics are presented in Table 2, expresses change in the costs of depreciation and amortization over sales. The results prove that more than 50% of all companies except CZ-NACE 21 (median) achieved relative growth in depreciation and amortization over their sales. In the case of CZ-NACE 22, the previous statement is valid for more than 25% of enterprises (3rd quartile). It means that such enterprises relatively massively invested into their fixed assets in the related time period. It must be noted that the results of full sample are influenced by the sample structure in which CZ-NACE 22 - Manufacture of rubber and plastic products dominates.

Table 2. Descriptive statistics of the indicator A

	Full sample	CZ-NACE 20	CZ-NACE 21	CZ-NACE 22
Mean	-0.0016	0.0004	-0.0079	-0.0018
Median	0.0013	0.0011	-0.0051	0.0015
Minimum	-0.3503	-0.1814	-0.1232	-0.3503
Maximum	0.1234	0.0975	0.0597	0.1234
1st quartile	-0.0073	-0.0047	-0.0240	-0.0075
3rd quartile	0.0101	0.0084	0.0132	0.0110
St. deviation	0.0346	0.0258	0.0356	0.0371

The second indicator B, whose descriptive statistics are presented in Table 3, expresses change in the personnel costs over sales. The results prove that more than 75% of all companies except CZ-NACE 21 (1st quartile) achieved relative growth in personnel costs over their sales. In the case of CZ-NACE 22, the previous statement is valid for more than 50% of enterprises (median). Employed cost items such as the permanent value adjustments of fixed assets and personnel costs should not be analysed only separately but their development should be analysed together.

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Table 3. Descriptive statistics of indicator B

	Full sample	CZ-NACE 20	CZ-NACE 21	CZ-NACE 22
Mean	0.0229	0.0265	0.0451	0.0200
Median	0.0206	0.0170	0.0211	0.0225
Minimum	-0.5373	-0.0874	-0.1473	-0.5373
Maximum	0.8140	0.8140	0.4286	0.3112
1st quartile	0.0010	0.0052	-0.0024	0.0003
3rd quartile	0.0448	0.0402	0.0760	0.0457
St. deviation	0.0722	0.0769	0.0978	0.0677

The third indicator C looks at previous two indicators jointly when the labour should be replaced by new technologies implemented. Negative values in Table 4 show that the personnel costs were not replaced by depreciation and amortization in most companies (1st quartile, mean, median, and 3rd quartile) and that the substitution had even opposite direction. The desired direction of substitution is observable in maximum values and in 3rd quartile of CZ-NACE 20 Manufacture of chemicals and chemical products. These results cannot be surprising if it is recalled that personnel expenses over sales of majority companies increased. This fact of increasing personnel expenses over sales can be caused by the labour market situation which is not helpful because of limited labour supply pushing up nominal wages and salaries. Other factor influencing the opposite direction of substitution could be that the companies did not invest into fixed assets and new technologies in the analysed period.

Table 4. Descriptive statistics of the indicator C

	Full sample	CZ-NACE 20	CZ-NACE 21	CZ-NACE 22
Mean	-0.0245	-0.0261	-0.0529	-0.0218
Median	-0.0202	-0.0162	-0.0359	-0.0224
Minimum	-0.8420	-0.8420	-0.3961	-0.3485
Maximum	0.4965	0.1213	0.0999	0.4965
1st quartile	-0.0459	-0.0427	-0.0789	-0.0466
3rd quartile	-0.0012	0.0012	-0.0072	-0.0011
St. deviation	0.0706	0.0827	0.0862	0.0638

The last indicator D addresses the profitability change observed in the data sample. Negative impact on profitability is proved by minimum, 1st quartile, mean, and median. Positive impact has been observed from 3rd quartile in all chemical sectors except CZ-NACE 20 - Manufacture of chemicals and chemical products which still has the slight negative impact.

Table 5. Descriptive statistics of the indicator D

	Full sample	CZ-NACE 20	CZ-NACE 21	CZ-NACE 22
Mean	-0.0213	-0.0269	-0.0372	-0.0182
Median	-0.0217	-0.0175	-0.0063	-0.0246
Minimum	-0.7861	-0.7861	-0.4610	-0.3176
Maximum	0.5782	0.1624	0.1948	0.5782
1st quartile	-0.0518	-0.0457	-0.0972	-0.0539
3rd quartile	0.0021	-0.0013	0.0234	0.0022
St. deviation	0.0885	0.0795	0.1193	0.0885

Previous comments related to the results of each indicator provide only partial analytical point of view. The interpretation should combine the indicators C and D and therefore discuss the dependency between the discussed inputs' substitution (expressed by the indicator C) and corporate sales profitability (expressed by the indicator D). Visualization would fit the paper's purposes the best as it is displayed in Figures 1-4. The horizontal axis presents the causative indicator C and the vertical axis represents the consequent indicator D. In the first quadrant, there are enterprises with a positive direction of observed substitution (i.e. substitution of human labor by technology) and with a favorable effect on the sales profitability. In the second quadrant, there are enterprises with a negative direction of substitution (i.e. on the contrary substitution of technology with human labour) and with a favourable effect on the sales profitability. In the third quadrant, there are enterprises with a negative direction of substitution and with a negative effect on profitability and finally in the fourth quadrant, there are companies with a positive direction of substitution but with a negative effect on profitability.

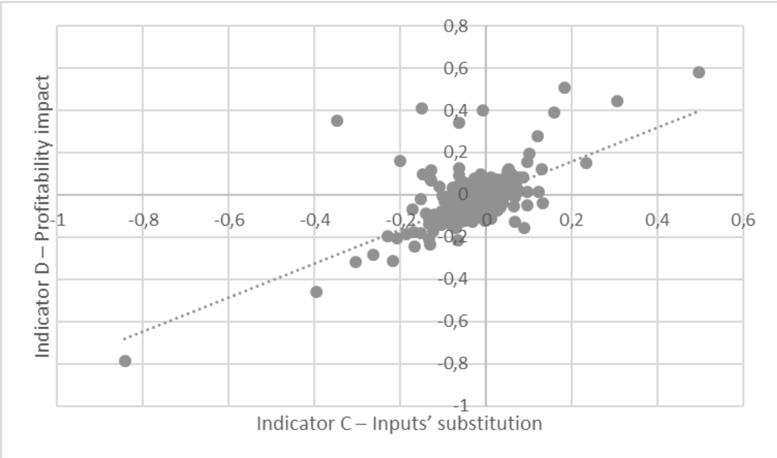

Figure 1. The effect of substitution on profitability – all chemical companies

It can be seen from the figures that for all monitored chemical sectors (Figure 1) as well as in each of them individually (Figures 2-4), the largest number of enterprises (63% of the total sample) are situated in the third quadrant. These businesses have shown the negative direction of substitution and the negative effect on profitability. In these enterprises, technology was substituted by human labor and this substitution influenced profitability negatively. Decreasing profitability can clearly be described as undesirable from the point of view of achieving the top corporate goal.

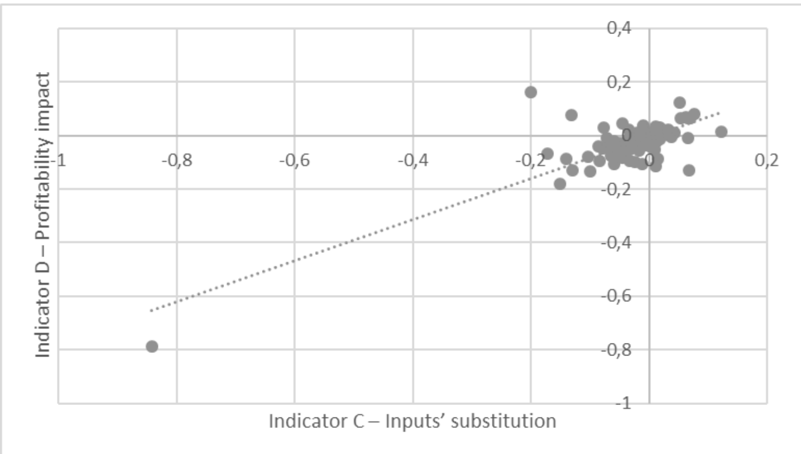

Figure 2. The effect of substitution on profitability – CZ-NACE 20

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The second place in terms of frequency of occurrence is occupied by the observations located in the first quadrant (14% of the total sample). This applies to the total data sample (Figure 1) and industry sectors CZ-NACE 20 (Figure 2), CZ-NACE 22 (Figure 4) but not to the industry branch CZ-NACE 21 (Figure 3). It should be reminded that the industry sector CZ-NACE 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations contains significantly less enterprises than other two chemical fields and such result could be influenced by the sample size. In the first quadrant, there are the companies with the positive direction of substitution having the favourable effect on profitability. Human labour has been replaced by technology in the terms of costs. This substitution is typical for the initiative of Industry 4.0. This replacement lead to the increasing profitability and that is desirable from the point of view of the top corporate goal.

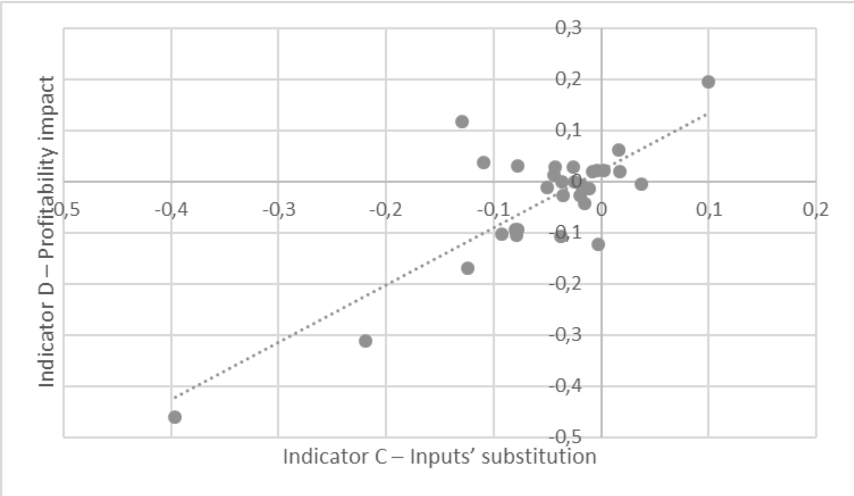

Figure 3. The effect of substitution on profitability – CZ-NACE 21

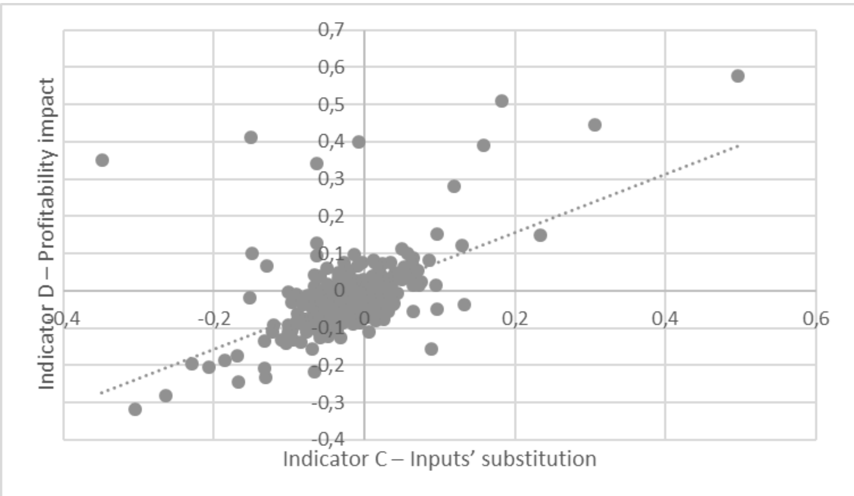

Figure 4. The effect of substitution on profitability – CZ-NACE 22

Figures 1 to 4 prove that there is the significant dominance of the business frequency in the first and third quadrant. In total, 77% of enterprises belong to these two quadrants. This leads to positive slopes of modelling regression lines in the total sample and also individually in each investigated chemical sector. Regression lines are displayed in each figure for the purpose of indicating and visualizing this described fact. The slopes positivity of these regression lines is the most important finding, illustrating the economic advantage of the Industry 4.0 innovations. Basic characteristics of regression models such as intercept, coefficient (slope), and R-Squared are presented in Table 6. The identified positive coefficients of the regression models express that the relative strengthening of the use of fixed assets in the analysed companies tended to the positive effect on the business profitability more often than the negative effect. On the contrary, the relative strengthening of labour inputs had the mostly negative effect on the corporate profitability.

Table 6. Regression models

	Intercept	Coefficient	R-Squared
CZ-NACE 20	-0.0069	0.7673	0.6377
CZ-NACE 21	0.022	1.118	0.6517
CZ-NACE 22	-0.001	0.7873	0.3216
CZ-NACE 20-22	-0.0016	0.8054	0.4129

The conducted research of the nature and economic effects of the analyzed substitutions in Czech chemical companies led to the finding of a lower occurrence of the substitution of human labor by technology compared to earlier research (Čámská, Klečka, 2020) carried out on logistics companies. It confirms previous estimates done by Malanowski, Brandt (2014) and Technický týdeník (2014) that the Industry 4.0 innovations will have a smaller impact on the chemical industry than on other business branches. It is worth emphasizing, however, that the desirable direction of substitution caused a favourable impact on profitability in most chemical companies in the Czech Republic. This corresponds not only to the conclusions for logistics companies in Čámská, Klečka (2020), but also to the basic theses of Industry 4.0 presented by Rüßmann (2015) and the McKinsey Global Institute (2014).

Some assumptions which allowed to conduct this quantitative research could be considered limitations. Each investment in fixed tangible and intangible fixed assets is supposed to belong to the Industry 4.0 innovations although the renewal investments or investments into standard machinery and software can be included. However, this statement does not weaken the conclusion that when the human labour is substituted by the technology, the positive effect on profitability and business performance has been observed in most companies in the Czech Republic.

It should be pointed out that the nature of the applied indicators presented in Methodology could result in some aspects of the possible inaccuracy. First, the consequences of the substitution are identified by the changes in relevant costs. Second, due to inflation and possible accelerated amortization and depreciation, there may be a certain relative overestimation of the indication of negative substitution (i.e. substitution of technology by labour). This applies to those companies that did not make significant new investments in fixed assets in the monitored period (three years in the case of this research). In order to accurately quantify and correct the influence of this factor, it would be necessary to investigate each company individually and include data outside of financial accounting. Such refinement could not be implemented due to the size of the data sample (containing more than 500 entities) and unavailability of the necessary non-account data. Although the mentioned distortion may mean an overestimation of the indication of the frequency and size of negative substitutions, it does not represent a fundamental obstacle for identifying differences in the effects of substitution on profitability between companies with positive substitution and companies with negative substitution of human labour by the technique. Third, the applied indicators do not operate with economic costs (especially the costs of capital employed) which would be relevant for the investments into fixed assets which require the retention of capital sources for their financing. The possible expansion of the standard financial ratios by the economic costs is explained in Klečka, Čámská (2020). There would be again the requirement to include also non-account data.

The selected time period on which the analysis is based can also affect the results received. The analysis has been conducted for the time period 2015-2018. First, this period follows the last non-pandemic global crisis and covers the time when the first innovations of Industry 4.0 should appear in businesses according to the years of publications discussed in the section Literature review. The serious consequences of the global crisis 2008-2010 should not be observed in the data sample anymore because the companies had enough time for recovery. More recent data would be adversely affected by the pandemic COVID-19 and the effects of substitution would not be visibly. Disclosure obligation of financial statements is not always respected by the companies operating in the Czech Republic (Strouhal et al., 2014) and it reaches a worse level when business companies are exposed to the existential difficulties (Bokšová, Randáková, 2013). The pandemic COVID-19 can be considered disruptive change leading to the business existential issues.

Conclusions

This paper contributed to closing the gap in the area of lack of research works focused on the economic effects of Industry 4.0. The paper's novelty is in the conduction of quantitative research with the emphasis on the replacement of labour by technique. The aim was to prove if Industry 4.0 has positive impacts on corporate performance. Technological shifts were presented by human labour substituted by technique.

The indication of a positive direction of the monitored substitution was far from predominant in the chemical companies in the Czech Republic in the monitored period. This could testify to the slow implementation of Industry 4.0 innovations. However, the observed relative strengthening of the use of fixed assets compared to the use of human labour in Czech chemical companies had more often a positive effect on their profitability (than the negative effect on the profitability). On the contrary, the relative increase in labour inputs compared to the value of the used fixed assets had a mostly unfavourable effect on the profitability of Czech chemical companies.

Received findings are worthy as the evidence to encourage the adoption of Industry 4.0 by practice and especially for policy makers when different projects and programs supporting the implementation of Industry 4.0 are prepared. Even if the obtained results illustrate and legitimize the economic advantage of implemented Industry 4.0 innovations in the chemical industry, a specific standard economic analysis will have to be carried out in the case when each company plans to implement a new investment project.

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