BUDAPESTI CORVINUS EGYETEM

EVOLUTION OF FDI HOSTING ECONOMIES IN THE CONTEXT OF THE RAPID WORLDWIDE DIFFUSION OF ROBOTICS TECHNOLOGIES

Analysing the Manufacturing Sector of the V4 Countries

THESIS

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Abbreviations

The following is the list of the abbreviations which are specific to the context of the study:

Abbreviation	Explanation
AI	Artificial Intelligence
DVA	Domestic Value Added
FDI	Foreign Direct Investment
FVA	Foreign Value Added
GVC	Global Value Chain
ICT	Information and Communication Technology
IFDI stock	Inward FDI stock
IFR	International Federation of Robotics
MIFDI stock	Inward FDI stock in manufacturing
MNE	Multinational Enterprise
MOFDI stock	Outward FDI stock in manufacturing
OEM	Original Equipment Manufacturer
OFDI stock	Outward FDI stock
TIER-1	Direct supplier of the final product
TiVA	Trade in Value Added
V4	Visegrád Four

1. Table: List of abbreviations

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Foreword

Several factors strengthened my motivation to undertake this course.

First, my background and environment supported international thinking. My grandfather, also a graduate of this university, introduced me to the fascinating world of international politics during my childhood. Besides, aviation, which is traditionally one of the most globalised industries in the world, was always around me. I was born into an "aviation family" and spent most of my career in this sector.

Second, I have worked primarily on European research and development projects during the last two decades. I performed several roles in these projects: researcher, project coordinator, analyst, dissemination and communication manager. Also, the domains covered were broad: economics, human factors, ICT, safety, security, etc., which were among the focus of these activities. Although the generalist, semi-expert approach in a vibrant environment was very interesting, it also became tiresome. I realised that I had primarily worked with researchers and university teachers who had been experts only in one field, an area where they could be good. This perception gave me the impulse to choose an area I could focus on.

Third, the era of the new industrial revolution in which we live inspired me to study related tendencies. Some researchers forecast that due to the latest disruptive technologies, our generation faces more transformations than humankind has ever been confronted with during the entire period of civilisation. Despite the foreseen tsunami of changes, the research activity in this domain is underperformed. There are headlines on the topic of automation, but little comprehensive research has been performed on the past, present, and future impacts of technological changes. For me, this is surprising, as I do not share the opinion of many researchers that new technologies are only one of the domains to study. On the one hand, the new solutions will probably help us to overcome our burning problems, like climate change and global poverty but on the other hand, they will cause new, different ones. Therefore, thoroughly investigating automation-related trends and their impacts on the economy and society is crucial and should be promoted.

1. INTRODUCTION

1.1. Research Target

1.1.1. Problem stating

The technology revolution is a global process that gets more and more attention nowadays. Engineers and STEM[1] scientists at companies and research organisations make tremendous efforts to progress in technological terms. Their research agenda follows a clear pathway: deepening the knowledge base in a particular sub-field or developing a new application in a specific domain. Although there is continuous improvement in nearly every field in our lives, the “big picture” is still uncertain; nobody knows where the world is heading with the flux of changes.

Economists and social researchers try to measure and forecast the impact of automation, but their studies often conflict with each other. One of the main related issues studied by economists and social researchers is the impact of automation on jobs. The main questions usually raised are: will automated solutions take over tasks previously performed by labour, and if yes, which sectors and job types are most impacted? To a lesser extent, social researchers also try to assess the geographic effects, e.g. how automation will affect foreign direct investment flows (FDI). Moreover, the technological impact of automation and robotisation and their influence on upgrading global value chains (GVC) are also considered.

However, the studies trying to answer the questions above usually concentrate on the leading industrial countries, like the United States and Western Europe. What is less researched in detail is the consequences of automation on countries that are catching up to leading industrial ones. Their position is interesting as there is a consensus in the literature that more developed countries are likely to gain more, and less developed countries are the relative losers of the process. In this study, I reveal that this statement is far from unambiguous by adding practical nuances to the general understanding of the effects of automation on less developed countries.

1.1.2. Study focus

The high-level question on the geographic effect of automation is very complex, and a full elaboration of it is unworkable within the limits of the current study. In this research,

[1] Science, technology, engineering, and mathematics

therefore, I narrow down the investigated subject where the effects are better demonstratable. The focus is on the different dimensions: the independent variable, the dependent variable, and the level of the application in terms of geography and sector.

The independent variable, in my case, is the current technology revolution. It has many linked terms, like Industry 4.0, digital revolution, etc. Here, I focus on automation in the original sense and deal with physical robots working in the manufacturing industry, which I refer to as robotisation. In terms of the examined area, I distinguish between automation and robotisation. Automation is a broader process that impacts everything: the manufacturing industry, transport industry, service sector, households and the IT industry in general (clouds, software maintenance, AI, etc.). Also, another crucial factor is that automation, as understood in most cases, is a relatively new process[2] in a growth curve; it is happening now, and even the framework within it could be considered forming. It is inevitably complex to analyse the effect of a process which is very wide and has little or (in some cases) no history[3].

Consequently, in my research, I concentrate on robotisation only. Under robotisation, I mean physical robots in the broader sense (not only humanoids), whose tasks are to execute physical actions automatically. One of the related definitions is: "a device that automatically performs complicated, often repetitive tasks (as in an industrial assembly line)" (Merriam Webster, 2023).

Making the investigated area even narrower, I concentrate only on robotisation in the manufacturing industry. The reason is that in this sector, robotisation is a phenomenon that has been introduced previously as the first industrial robot, Unimate, was produced in 1961 and installed in GM's factory for die casting handling and spot welding. As robotisation was widespread in the 70s with a higher magnitude, approximately half a century of data is available on efficiency gains, costs, and benefits.

The manufacturing industry's choice is underlined by its relevance for developing an economy, as "most high-income countries achieved that level of prosperity through manufacturing export-led strategies" (Hallward-Driemeier et al., 2017). Besides, the

[2] Automation in a simplistic form was present for long. However, recently, it has started a new path, it is no longer a mechanical support for certain workflows, but rather a new, powerful revolution.

[3] I use the term "no history" for recent automation related sub-applications, like the new generation AI based chatbots.

emerging East-Asian countries also built their success with the help of the focus on manufacturing activities (Hallward-Driemeier et al., 2017).

The dependent variables support the measurement of the economic impact of robotisation.

First, robotisation impacts labour. While the impact of automation on jobs is a global issue, the level of impact differs geographically, depending on the characteristics of a certain country or region. Therefore, the analysis of the changes in the employment-related indicators is appropriate.

The second chosen indicator is foreign direct investment (FDI). The changes in both the volume and nature of FDI stock are relevant in this context. FDI has become a valuable tool in the international economy; FDI-based growth is a tool for many less developed countries to try to catch up with the leading ones. As its importance grew, attention increased to understanding its motives, especially nowadays, as a large part of FDI is implemented within global value chains (Xing et al., 2021). Therefore, the primary area of my research is the flow of the more controlled FDI, which is implemented within a GVC.

Third, robotisation tendencies generally accompany technological upgrading. This means that a certain country or region develops its innovation and industrial capabilities faster than the average country. Consequently, technology upgrading-related indicators will serve as the third stream of dependent indicators.

Fourth, upgrading can be measured as positions within global value chains as GVCs have growing significance in the global economy. Accordingly, the position of the investigated countries in the GVCs will be analysed.

In terms of applying the research, there is a geographical and a sectoral concentration. The geographical focus is the Visegrad Four countries (the Czech Republic, Hungary, Poland, and Slovakia). The reasoning is that these countries have achieved remarkable results in terms of the FDI inflow. First, inward FDI (IFDI) is important for these economies as FDI-based growth has contributed significantly to their GDP increase over the past decades. FDI was a dominant tool for them to catch up since the system change in 1989 (Sass, 2021). FDI stock is a useful variable that shows the success of FDI over a more extended period. The V4 countries are kind of "champions" in attracting inward FDI; they possess 1.5% of the global IFDI stock, while their share is only 0.8% of the world population and 1.3% of the worldwide GDP (Kalotay et al., 2021). This difference also stands when examining a more extended timeframe (back to 1993). It can be observed that the V4 countries: "..had considerably higher levels of FDI stock to GDP than the OECD countries as a whole, and also than the European Union member countries (with the exception of Poland)" (Sass, 2021).

The second argument is their development status. As mentioned earlier, the mainstream thinking is that there is a negative effect on production outsourcing from leading industrial countries to developing countries. However, the impact on so-called "catching-up" countries, which are somewhere in between the two categories[4], is less explored, and the Visegrad Four (V4) economies are in this category[5]. Third, they are considered vulnerable as they depend on IFDI (Nölke, 2009), and the subsidiaries of multinational companies are dominant players in many aspects within these countries (Sass, 2020).

The sectoral focus, manufacturing, was already detailed above. The V4 countries are engaging in this respect as well; the manufacturing industry is relatively significant in the FDI inflow to this region (Veres, 2018). As within this category, automotive is especially important (Novekedes.hu, 2022), most of the cases in the analysis are from this industry.

Based on the problem setting and the focus areas, the ultimate question[6] to study is the following:

How do FDI hosting catching-up countries, like the V4, develop during the era of swift robotisation?

1.1.3. Timescale

The timescale of the analysis is approximately the last ten years; some parts of the analysis use an earlier starting value (e.g., earlier than 2013), and some of the investigated periods close earlier, e.g., in 2019. Data availability and relevance are the key factors in deciding the time period studied for a specific analysis. In general, the last ten years are long enough to depict trends, but at the same time, the data investigated is contemporary.

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[4] The V4 countries are developed economies, but as it is introduced later, in terms of their position in FDI flow and upgrading in GVCs they show similarities to some developing economies.

[5] The catching-up status is underlined by the fact that the Central Eastern European economies have been growing at a larger rate than the average of the European Union since 1990 (Molterer et al., 2022).

[6] This high-level question is not equivalent to the research questions, which are formed later.

1.2. Research Objectives

1.2.1. Research justification

Although a significant number of studies have already been prepared on the current and potential future effects of robotisation on foreign direct investment flow, jobs, and upgrading, there are still significant potentials in exploring this topic. The reasoning is the following:

1, Despite the earlier quoted prophecy from Keynes (Keynes, 1933), until recently, the mainstream understanding among economists was that technology development contributes to growth and welfare, and this view has a strong position even today (Autor, 2015; Holzer, 2015). Therefore, the papers and books trying to call attention to the possible negative economic and social implications of the technology development tendencies are *new* and still represent a smaller quantity, especially if mainstream economics books are also considered.

2, Most studies dealing with the economic impact of automation and robotisation focus on the possible substitution effect of technology versus labour *within* one economy, which is, in many cases, the USA (Ford, 2015) or they scrutinise the impact on selected leading industrial countries[7]. Less attention was given to the "catching-up" countries, like Central- and Eastern Europe for example.

3. Even the researchers conducting studies on the effects of robotisation claim that *more* research is *needed* in this field as the current results are not noticeable: "the robotics revolution is (only) in the beginning stages, and the potential impacts may not be observed yet" (De Backer et al., 2018). Consequently, on the one hand, the technology revolution is here. Its quick pace is acknowledged together with its potentially significant impact (Manyika et al., 2018), but at the same time, it is also noted that the research performed so far is not sufficient, primarily due to the limited amount of information and data assessed so far.

4. The fourth and last observation is that research performed in this niche area usually sharply distinguishes between leading industrial and developing economies (De Backer et al., 2018). The *contrast* is often unclear: to which category does China currently

[7] Under leading industrial countries I mean countries like the G7 members and China.

belong? What is the status of the newer member states of the European Union in a global context?

Therefore, I chose to analyse the effects of robotisation on the foreign direct investment flow, jobs and upgrading potentials. I examine these factors in the context of the manufacturing industries of the Visegrad Four countries. The reasoning is that these countries are highly FDI-dependent economies with a significant focus on the manufacturing industry; they are facing turbulent changes in their jobs market, and they are eager to upgrade to the Western economies, embedded into global value chains and positioned in between the leading industrial and the developing economies.

1.2.2. Research questions and hypotheses

1.2.2.1. Research Question 1 and the related hypothesis

The assumption is that the investment in the manufacturing industries of V4 countries is impacted by the ongoing automation process in the home factories of the large multinational companies in leading industrial countries. Thus, the increasing robotisation in the leading FDI-sending countries might decrease the volume of investments in the V4 and can even lead to the backshoring of production from the V4 to the headquarters factories. Consequently, the first research question in the V4 context is:

Research Question 1. *How does the increasing robotisation in advanced economies affect the volume of foreign direct investments in the manufacturing sector of the V4 countries?*

The hypothesis is that there is an effect of robotisation on investments in the V4 countries:

Hypothesis 1: Robotisation-related growth in the leading industrial countries has a negative impact on the foreign direct investments from the leading multinational companies in the manufacturing sector of the V4 countries.

1.2.2.2. Research Question 2 and the related hypothesis

My presumption is that the V4 countries benefit from the current industrial revolution, and there is a technological upgrading in progress in the V4 countries. Accordingly, the second research question is:

Research Question 2: *Is there a technological upgrading towards the leading industrial countries in progress in the V4 region?*

The concerning hypothesis is the following:

Hypothesis 2: The global technological advancement supports the technological upgrade in the V4 countries, mainly through the subsidiaries of large multinational companies.

1.2.2.3. Research Question 3 and the related hypothesis

The consideration is that the technological development in the V4-located subsidiaries of large multinational companies also fosters upgrading in GVCs. The related research question is as follows:

Research Question 3: *Does the technological development in the subsidiaries of large multinational companies in the V4 stimulate upgrading the subsidiaries in the global value chains?*

My hypothesis is that these developments support the V4 subsidiaries to establish better positions in GVCs:

Hypothesis 3: The technological development in the subsidiaries of the large multinational companies in the V4 promotes upgrading these units in the global value chains.

1.2.2.1. Research Question 4 and the related hypothesis

Forecasts say that the number and type of jobs will shrink due to automation; some researchers find that this process is already ongoing (e.g. Ford, 2015). Besides, there is an assumption that robotisation will benefit skilled workers at the expense of unskilled ones. As the manufacturing sector of the V4 countries is embedded into GVCs, the expectation is that the job market of these countries is affected e.g., there is less need for manual workers due to the increasing robotisation level.

Research Question 4: Does the increasing robotisation in manufacturing sites of multinational companies in the V4 decrease the need for manual workers in the V4 subsidiaries?

Hypothesis 4: The hypothesis is that the increase in the level of robotisation in the manufacturing sites of multinational companies in the V4 region impacts the number and type of workers employed.

1.3.Methodology

Understanding the impact of robotisation on the economies of catching-up countries like the V4 is a complex task, therefore, an adequate and complex methodology should be invented. Consequently, my research uses quantitative and qualitative approaches, both applied at macro and micro levels.

The following table (2. Table) shows a high-level summary of the tailor-made methodology framework, whereas the subsequent sub-chapters provide a detailed explanation.

	Quantitative	**Qualitative**
Macro-level	• relation of robotisation rate growth rate and the outward FDI stock to the manufacturing industry • analysing the employment-related statistics in the V4 • trade in value-added indicators tendencies • investigating other development-related indicators	• Scrutinising the FDI, backshoring, employment, technology and GVC-upgrading related trends in the leading developed countries and the V4 countries, based on interviews with experts and desk research on the relevant literature
Micro-level	• comparison of annual report information for global companies and their subsidiaries in the V4 focusing on employment-related differences	• Interviews with local (V4) managers of selected multinationals from the main FDI-source countries, discussing issues such as automation tendencies, employment possibilities, signs of backshoring, upgrading in GVCs, catching up to leading Western economies, etc.

2. Table: The methodology matrix

The table shown above depicts the process-based methodology applied when conducting the study. However, the thesis itself follows a result-based framework, where the subsequent sections (the literature review, the analysis, and the interpretation of the results) are organised according to the main research questions.

1.3.1. Macro-level quantitative analysis

The macro analysis is the starting point; here, the data and the qualitative characteristics are considered at the country level. Within the FDI-related macro-level investigation, the first step is the quantitative analysis: I aim to find a general link between changes in the robotisation rate and foreign direct investment out- and inflow stock. The primary tool used is a regression model where the robotisation level is independent, and FDI stock is the dependent variable. In order to transform the data set to one from which tendencies can be observed, I also apply trend analysis.

The input information is from the OECD statistics (OECD, 2023) on FDI and the International Federation of Robotics (IFR) database (IFR, 2023a). In terms of robots, I consider the number of industrial robot stock applied in a particular country on a yearly basis. As a first step, I check the overall tendencies of robotisation in the major developed economies and the V4.

When investigating the FDI, my primary focus is on manufacturing related FDI. Thence, what is interesting to see is the changes (trend) of outward foreign investment stock to manufacturing (MOFDI), especially the difference between MOFDI and general outward foreign direct investment (OFDI).

MOFDI is analysed at the level of the major developed FDI-source countries, and the tendencies are introduced in a more detailed form in the case of the selected countries.

Regarding the V4, the changes in the robotisation rate and the inward foreign direct investment to the manufacturing industry are considered (MIFDI trend).

Also, the trade-in value-added indicators give information on the GVC integration and the upgrading tendencies in both the leading robotised and V4 countries.

In addition to that, the V4 economies are assessed in statistical terms. The statistics give information to analyse the upgrading both in technology and within the GVCs. Besides upgrading, the employment-related data in these economies is also investigated.

1.3.2. Micro-level quantitative analysis

The micro-level quantitative analysis is an assessment of the balance sheets of two leading multinational companies in the V4 countries with respect to changes in key performance indicators (KPI), which can be relevant for the volume and the quality relevant aspects of FDI decisions. The KPIs focus on the changes in the number of manufacturing employees over the last few years. Comparison is made between the level of changes at global level versus the factories in the V4 countries. Due to the availability and the nature of the data, the micro-level quantitative analysis is mainly used to fine-tune the answers to certain research questions.

1.3.3. Macro-level qualitative analysis

The forthcoming milestone is to put the numbers developed in the macro level quantitative analysis into context: analysing the V4 countries in the context of robotisation tendencies. The examination builds on desk research and interviews. Interviews are conducted with investment promotion agencies, researchers and a government official to cross-check what is behind the numbers explored in the quantitative part of the macro analysis. The field research was executed during the autumn of 2022 and the winter of 2022/23[8].

The Hungarian experts have an extensive background, while the interviewees from the other three V4 countries are university teachers in economics. A list of questions was prepared for the semi-structured interviews (Willis, 2006), but the discussion implementation gave the interviewees some flexibility in focusing more on certain topics.

The table below shows the interviewed persons' nationality, position and the type of organisation they represented (3. Table).

[8] The interviews with the experts also supported the preparation of two articles and the related parts of the analyses builds on them (Guraly, 2023 and Guraly, 2024).

Country	Type of organisation	Position of the interviewees
HU	automotive networking organisation	managers of the organisation
HU	innovation network	managers of the organisation
HU	research organisation	researcher
HU	innovation management	manager of the organisation
HU	government agency	investment promotion expert
PL	university	professor of economics
CZ	university	professor of economics
SK	university	professor of economics

3. Table: The characteristics of the interviewed experts

The interviews were dominantly implemented on a one-to-one basis, but on some occasions, more than one participant from the same organisation answered the questions. The questions were originally the same for everyone, but there was a shift in some cases, focusing more on topics that were more relevant to a particular organisation or expert.

For most of the sub-research question-related findings, the relevant literature is also presented using data triangulation (Bhandari, 2023).

The main directions of the analysis are to explore if there are backshoring-related motivations, what the technology upgrading-related tendencies are, and if there are signs of upgrading in global value chains.

1.3.4. Micro-level qualitative analysis

Similarly to the macro one, the micro-level qualitative analysis also builds on field research. Managers of Hungarian subsidiaries of large multinational companies were interviewed during the autumn of 2022[9]. The structure of the interviews was similar to the ones described in the section above for the macro-level analysis. The managers interviewed were from different positions, mostly from the automotive industry (4. Table).

[9] The results of the interviews with the managers were also used in two articles (Guraly, 2023 and Guraly, 2024).

Country	Type of organisation	Position of the interviewees
HU	automotive OEM[10]	production leader
HU	automotive OEM	CEO[11]
HU	TIER – 1[12] vehicle company	R&D director
HU	TIER – 1 automotive company, OEM in other fields	CEO
HU	TIER – 1 automotive company, OEM in other fields	Group Leader
HU	TIER – 1 automotive company	2 Operations managers, 1 line manager
HU	OEM in healthcare	Project Manager

4. Table: The characteristics of the interviewed managers

The motive was crosschecking the quantitative results and macro-level qualitative interviews with real-life feedback: how experts in the area interpreted the FDI-related trends, shifts in employment and whether they observed upgrading of the V4 countries in terms of technology and GVCs.

1.3.5. Limitations and solutions

Data reliability

Concerns can be raised on the reliability of both the robotisation and the FDI data. In terms of robots, the question might be, what is a robot, and how can it be quantified in a coordinated manner on a global scale? With regard to FDI, problems arise due to the indirect activities of multinational companies; some of the FDI processes in the statistics are not related to an investment in reality (Antalóczy et al., 2014; Sass et al., 2019)

However, for both indicators, the data is collected from reliable sources: IFR for robotisation and OECD for FDI. There can be some issues with the accuracy of the absolute values for FDI and with the robotisation-related indicator, but as they are, in all cases, generated by the same organisation with the same metrics, they provide a good basis to observe tendencies. Also, keeping the indicators simple supports the calculations

[10] Original Equipment Manufacturer

[11] Chief Executive Officer

[12] Direct supplier of the final product

and eases the understanding of the analyses. Besides, qualitative research augments the quantitative results and helps to correct the possible shortcomings of data quality.

Qualitative aspects and other technology developments

The independent variable of the FDI-related analysis is the number of robots in use in developed countries[13]. The choice of this factor might raise two concerns: one about the missing quality element; the other is the narrowness in scope. In terms of the first one, the quality aspects of robots and data availability are limitations. The IFR database provided for researchers contains only the volume of robots without additional characteristics. However, even though qualitative aspects of robots would be available, this would not support the analysis to a large extent. The reason is that the research is conducted at the country level, and the qualitative aspects of robots cannot be measured with such large numbers[14]. The other issue is the scope of the analysis. The inclusion of other elements of the current industrial revolution in the analysis would make the analysis framework unnecessarily complicated. The timeframe (mainly the last decade) and the scope (the manufacturing industry) make it possible to avoid including artificial intelligence, for example, in the analysis. Robots were already widespread and significant in number during the last decade, while the AI revolution was just about to start[15] (Huang, 2023).

Focusing on robots only has limitations, as explained above. However, choosing a well-quantifiable independent variable supports the integrity of the analysis. In addition to that, the qualitative analysis enabled experts and managers to examine other technology development factors.

Size of research samples

Another risk regarding the study is the size of the research sample in the field research. In other words, to what extent do the selected experts and managers represent their industry? To what extent can I rely on my findings from the respondents' feedback? This is a relevant question in any qualitative research. I tried to overcome this problem in two

[13] Robotisation is also measured in the V4 countries, but for a different reason as explained in the analysis.

[14] The order of magnitude is some hundred thousand robots in case of the leading robotised countries.

[15] Artificial intelligence is not a new phenomenon in terms of engineering and research and development, but it is starting to make a substantial impact on the economy and the society only nowadays.

ways: by choosing experts with vastly different backgrounds and by using data triangulation.

As mentioned above, selection was one way to ensure representativeness. Different backgrounds were ensured at three levels: type of organisation, type of job function, and geography.

First, when selecting the interviewees, I paid particular attention to having experts and managers in the sample; their share was approximately the same among the overall respondents. Experts were meant to provide feedback on macro-level tendencies, while managers were expected to bring up micro-level cases. Nevertheless, a significant part of the managers' answers was generic and therefore supported the macro-level qualitative analysis. In terms of organisations, companies included both OEMs and suppliers. Regarding product types, high-value, complex products and low-value products with simple manufacturing activities were also included in the portfolio.

Second, variety in the job functions was another essential point. Among managers, there were CEOs, operational directors, a research centre leader, a project manager, and line managers to ensure a wide representation of the different functions related to manufacturing. Within the expert group, university teachers, automotive experts, researchers, SMEs, and innovation support providers are found.

Third, regarding geography, Hungary was the focus of the research for practical reasons. Within Hungary, a wide geographical coverage was ensured; the factories in the sample were dominantly from the countryside. To ensure that the Hungarian results are also valid for the other three V4 countries, university teachers from the Czech Republic, Poland and Slovakia were interviewed. These interviews were organised at the beginning of 2023 after the first round of interviews with Hungarian respondents was finished and assessed. The university teachers were selected based on their knowledge in the field. They all frequently publish papers on the related subjects: FDI, automation and the manufacturing industry.

However, as the topic is complex, I tried to ensure that the findings aligned with those in the literature. Therefore, using data triangulation (Bhandari, 2023), the most important results of the field research were cross-checked with the relevant outcomes of my desk research. Moreover, the matrix of the quantitative and qualitative and macro- and micro-level analysis framework was designed to scrutinise the topic thoroughly.

2. THEORETICAL FRAMEWORK

2.1. Literature review

This section covers the literature relevant to the three research questions, e.g. it includes the assessment of articles and studies in the field of:

- employment,
- foreign direct investment,
- technological upgrading,
- upgrading in global value chains.

Although I try to analyse the most essential writings in each category, the focus is on research that includes the considerations of automation[16] and/or robotisation.

2.1.1. Employment

When analysing the impact of automation on employment, the usual questions emerging are: Will robots take the jobs? If yes, when? Which jobs? To what extent? As work is tightly linked to human beings, this area is in the spotlight of automation-related research. The related research can be sectioned according to the related theories, the benefits—and disadvantages, and the sectors affected.

2.1.1.1. Growth theories

Growth theories are the most relevant to employment. In the endogenous models, economic growth is the result of internal variables. In one of the related studies (Romer, 1990), growth is related to the investment in human capital. Contrary to the above-mentioned models, growth is related to external variables in the exogenous models. The production function is the main theory related to it. The latter is important for my research in terms of representing the two main substituting factors in capitalism: capital and labour (Solow, 1957). Robots can also be considered a form of capital (Battisti et al., 2022). A more recent form of the production function is set by Mankiw (2009):

$$\mathbf{Y=F(K,L)}$$

1. Equation: The production function, according to Mankiw

Where,

[16] As mentioned earlier, the focus is the thesis is rather robotisation than automation, but as there are more studies available on the later one, articles on both terms are analysed in the literature review.

Y: is the output of goods

K: is capital

L: is labor

De Backer and his co-authors also find this relation: "manufacturing industries in which labour costs account for a large(r) share in total production costs are more likely to invest in robotics because robots allow to save on labour and thus costs" (De Backer et al., 2018)

2.1.1.2. Robots and jobs

Until recently, the mainstream understanding among economists was that technological development plays a positive role in the economy and supports society. Autor (2015) expects that workforce polarisation will not continue indefinitely, and a significant number of middle-skill jobs will exist in the coming decades as he believes that many tasks bundled into these jobs can only be unbundled with a substantial quality decrease. He also cites the Polanyi paradox[17] as it helps to understand what has not been achieved and what else is likely to be completed by automation. This "don't know the rules" applies to two types of automation processes: environmental control and machine learning. In environmental control activities, the limitation of machines in executing specific tasks and the human ingenuity to re-engineer circumstances to avoid obstacles can be observed. (Autor, 2015). Furthermore, it is seen that although many jobs in the middle of the US job markets are decreasing in number, another set of middle-skill jobs is consistently growing, and, in some cases, there are not enough applicants to fill the vacancies (Holzer, 2015).

A study in the field showed that Industry 4.0 would benefit Germany (as a selected case study due to its leading position in technology upgrading) in four areas: productivity, revenue growth, employment, and investment (Russman et al., 2015). Another example of the positive link is that the rapid increase in the US in the 90s was primarily due to the high-tech revolution during that time (D. Oliner et al., 2000). The main problem with this "positive" approach is not the "positiveness" but the neglect of the changes in the nature of technology development. They deliver answers to the issues raised on the basis of

[17] Polanyi thought that "we know more than we can tell", meaning that in many cases the human being acts tacitly, without knowing the real rules behind the activities. (Autor, 2015)

current empirical data and fail to address the middle and especially the likely long-term tendencies.

It is also important to understand what technology means, as different researchers have different interpretations or focus only on technology's sub-elements. In an article, the impact of ICT infrastructure development on economic growth in the European Union was analysed. A significant positive relation was found by empirically examining the implications for all the countries for 18 years (Toader et al., 2018). Here, the main issue is a terminology one; as for my research, those articles are relevant which go beyond the effect of the simple quantitative development of digital infrastructure.

On the other hand, other researchers foresee significant problems in the labour market. These fears of technological advancement are not new. Keynes warned nearly a hundred years ago: "due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour" (Keynes, 1932). Recent arguments show that the time has come to make this prophecy real: the development process is different and dangerous as the lost jobs might not be substituted with the same number of new jobs. The potential effects of ICT developments, e.g., artificial intelligence and big data analysis, are underestimated as full automation is achievable (Ford, 2015). Expressed in a more economist terminology: "..artificial intelligence and machine learning could allow computers and robots to increasingly replace labor in the production function for goods" (Fernald et al., 2014). According to Ford, this is not only about the future: workers in the competitive industry in the USA worked 194 billion hours in 1998 and 2013. However, the same number of working hours was achieved when the country's population was larger by 40 million, many more companies were operating, and the value generated was 42% higher (Ford, 2015). This finding aligns with another empirical study, which estimated that approximately 25% of US jobs are offshorable. Production work, office, and administrative jobs can be most affected, and industries, mainly manufacturing, finance, and professional and technical services, are endangered (Blinder et al., 2013).

Josten and Lordan (Josten et al., 2019) investigated patents to examine to what extent different European economies are vulnerable to automation. They found that 47% of all jobs will become automatable in the next decade, corresponding to the findings of Frey and Osborne, as they estimated a 42% potential loss of employment (Frey et al., 2013).

They separated “automatable” and “fully-automatable” employment. The difference is “polarised” automation; in this case, the new solution would still require human involvement to function correctly.

Many researchers are halfway between the two opinions and have moderate reasoning on the impact of automation and robotisation on jobs. An OECD study finds that “about half of all workers will confront the need to significantly adapt to the new workplace environment” (OECD, 2018). The debate usually focuses on the pluses and minuses, but a common denominator is that the effects will be enormous: many experts forecast significant changes in the related consequences (Manyika et al., 2018). It was also found that the elasticity of demand for a specific type of goods affects whether productivity-improving technology change increases or decreases the labour needs in a particular sector (Bessen, 2019).

Acemoglu and Restrepo tried to build a more systematic approach; they did not agree with the forecasts for the near-time dangerous impact of automation. On the other hand, they did not support the claims that technological changes are always favourable for employment. They found that the “the recent stagnation of labor demand is explained by an acceleration of automation, particularly in manufacturing, and a deceleration in the creation of new tasks too”. They showed that if the growth continues to be automation-driven, then the positions of labour will decline. (Acemoglu et al, 2018) Following this trend among economists, it is demonstrated by using an extended production function and calculating elasticity among workers and AI technology that the new developments will have a negative effect on wages “unless the returns to robotic assets are broadly spread across the population” (DeCanio, 2016).

The job market is also following automation trends. It was found that employment in the USA is U-shaped in skill level, while there is an increase in jobs in the lowest and highest job-skill quartile, and there is a relative decline in the middle of the distribution. However, the effect of technology is not only negative on the labour market: “as technology substitutes for labour, there is a destruction effect, requiring workers to reallocate their labour supply; and second, there is the capitalisation effect, as more companies enter industries where productivity is relatively high, leading employment in those industries to expand.” The aggregated result is challenging for workers: there is a process of pushing skilled workers down the occupational ladder, which might cause low-skilled ones even to be unemployed. (Frey et al., 2013)

Other empirical analysis pointed out the correlation that "different robot densities across the world and the European economies clearly respond to the economic assumption: high labour costs are coupled with high robot densities while low wages are accompanied with low robot densities" (Cséfalvay, 2019).

The balanced approaches seem the most relevant for my research for two reasons. As my research focuses on the past (although the very recent past), the pessimistic forecasts are not relevant. However, it seems to be clear that the previous attitude towards automation, which emphasised only the positive effects on the economy, is not maintainable; due to the geographic differences, the benefits of the technology are distributed unevenly. Those balanced works that try to analyse the situation within a framework are particularly useful for my study. First, they present a structural option for measuring the positive and negative effects of automation. Second, they show what factors are crucial to be measured.

2.1.1.3. Impact of automation on the manufacturing industry

Regarding the sectoral impacts, those research studies are interesting for my thesis which focus on the manufacturing industry. A report from PwC (Hawksworth et al., 2018) explains that automation will affect different sectors unalike. In terms of potential job loss, the manufacturing sector is the second after transportation and storage. According to their calculations, in the manufacturing industry during the 20s, approximately 20% of the jobs can be lost and during the first half of the 30s, another 20% (Hawksworth et al., 2018). Impacts on the manufacturing sector are not foreseen only in the future; they are present, according to a recent empirical study (Compagnucci et al., 2019). The research assessed the effects of the increase in robotisation on labour and wages in 16 OECD countries. The following was found on the increase in robotisation (in sectors where robotisation is growing at a faster pace):

- it decreases the growth of hours worked,
- increases the hourly wages in the same industry,
- total real wages increase at a slower pace,
- price growth increases at a slower pace.

The justification for the last finding is that robots increase the overall output, which generates an attempt to increase the sales volume, and for that, lower prices are needed (Compagnucci et al., 2019).

Fernández-Macías and his co-authors (Fernández-Macías et al., 2021) augment the understanding of industrial robotisation in Europe with a new perspective. They discovered that:

- There is only incremental development in robotisation technology, and the recent European robots are just updates on earlier solutions. They observed no disruptive element in the current robotisation tendencies.
- Robotisation is very concentrated. In terms of industrial sectors, there are only three where the robotisation rate is significant: automotive, plastic, and metal products. With regard to geographical concentration, they calculated that nearly half of the industrial robots are employed in Germany.
- The sectors where the increase in robotisation was higher are those where the share of routine tasks is high and there is a relatively lower share of highly educated workers, but at the same time, the wages and labour union membership are higher.

Due to these findings, they state that "These robots are more likely to replace less sophisticated robots than human workers" (Fernández-Macías et al., 2021). However, it should be noted that the period investigated was from 1995 to 2016, and significant progress has been made during the last years in the field. They also mention that the emergence of artificial intelligence might change the "non-disruptive" nature of robotisation.

In another study by the same authors (Klenert et al., 2023), it was revealed that there is a positive correlation between robotisation and total employment in Europe. They also did not find a negative impact on the employment of low-skilled workers in manufacturing sites. Furthermore, they claim that the higher the level of automation in a particular industry or country, the more resilient they are against the decline in employment (Klenert et al., 2023).

2.1.2. Foreign Direct Investment

Similarly to the studies on employment, foreign direct investment is analysed at two levels. First, I introduce those theories that I can use in my analysis, and second, I highlight those that already show the possible link between automation/robotisation and FDI.

2.1.2.1. Relevant FDI theories

I chose FDI as one of the indicators to measure the impact of robotisation because it is considered a paramount index when measuring a country's economic performance. From a methodological point of view, it is important that in the FDI literature, there is a differentiation between outward foreign direct investment (OFDI) and inward foreign direct investment (IFDI). The first is the cross-border flows in value from the reporting economy, the second is the capital inflow to the receiving country. Besides the yearly flow, the stock is also measured, which means the total direct investment level at a given time (OECD).

The usual impact associated with FDI is that it generates economic growth. Baiashvili and Gattini (2020) did a robust empirical investigation to test this link. They found that the impact is there, but it varies by a large extent depending on the country’s income level. They observed a “statistically significant inverted U-shaped relationship between countries’ income levels and the size of FDI impact on growth”, meaning that low-income countries were less impacted, the highest impact was on middle-income countries, and high-income countries were also less affected by the FDI (Baiashvili et al., 2020). Another finding was that within the specific income group, countries with a better institutional framework (e.g., more efficient legal and governance framework, less corruption, etc.) performed a more significant growth level on the same FDI level (Baiashvili et al., 2020.). Feldstein mentioned other benefits associated with inward FDI, such as access to new technologies, human capital development through employee training, and the generation of profits and taxes (Feldstein, 2000). Besides the direct economy-related benefits, FDI can also support soft skills development (Fifeková et al., 2015).

However, not all researchers consider FDI ultimately beneficial. Nölke realised that the CEE countries dependent market economies, as they relied on the investment decisions of multinational enterprises (MNEs) (Nölke, 2009). Pavlinek (2016) did a study on East Central European (ECE) countries (a broader zone which contains Central Eastern Europe and some other countries) and found that strong FDI dependence in these countries has serious drawbacks. He mainly showed via Slovakian examples - which is the largest producer of passenger cars per capita (Spectator, 2015) - that leading MNEs mainly chose their ECE locations due to the significant wage differences as they planned to increase their global competitiveness by offshoring labour-intensive production to lower cost, peripheral locations. The EU membership and the close location to the Western markets also matter, but the key is the wage-related factors and the flexible labour policies (Pavlinek, 2016). It was shown that "the maquiladora strategy promotes the development of 'low-wage, low or medium-skill, low value-added manufacturing' with limited chances of upgrading in the foreseeable future" (Ellingstad, 1997). On a broader scale, analysing Central-Eastern European economies, a study revealed, while German home plants of leading German MNEs focused on vocational skills, the CEE plants were characterised by a much greater reliance on semi-skilled work (Krzywdzinski, 2017). These conclusions are important for my study as they justify the geographic selection: as the V4 countries seem to be vulnerable to their FDI dependence, it is particularly interesting to see whether robotisation affects investments in these countries and, if yes, how.

There are micro-level (e.g. firm) and macro-level (usually country) theories related to foreign direct investment. One of the most important in the first group is the OLI paradigm[18] (Dunning, 1980). The OLI paradigm categorises the factors that impact firms' decision-making into ownership, location, and internalisation advantages. From this list, location-specific advantages are particularly relevant, as differences among locations can cause additional benefits. The "push" and "pull" factors are also related to the location advantages. Push factors are the internal or domestic factors that enable and force the organisation to seek investment outside its home country; pull factors make a particular firm/location/country attractive to the investor. One of the key principles for categorising them is by the investor's motives: the decision can be based on market-seeking, resource-seeking, efficiency-seeking, or asset-seeking. Many factors can be found within the categories, for example, market size, market growth, access to regional markets, country-specific consumer structures, etc. (Dunning 2004). The OLI paradigm, together with the push and pull factors classification, is a useful tool for my research as it systematically analyses both the driving forces behind a company to invest abroad and, simultaneously, the approach to analyse the attractiveness of the destination-set of the capital.

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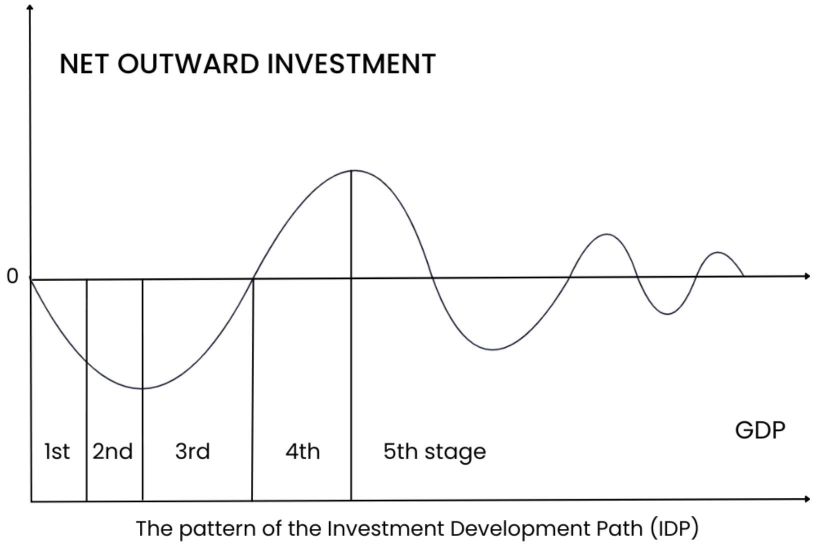
[18] Also called as the "Eclectic paradigm".

Among the macro-level theories, the investment development path (Dunning et al. 1993) is also useful for my study. The theory shows five stages a country can go through regarding its relative position in foreign investments to the rest of the world (1. Figure: The investment development path1. Figure). This can be considered an upgrade of the product life cycle theory (Vernon, 1966) and fits better to my research as it is more detailed, and the exact position of the Visegrad Four countries on this "path" is particularly interesting.

The different stages on the investment development path are the following:

- Stage 1 means that the country is relatively underdeveloped with low location advantages to attract significant inward FDI.
- When a country is at Stage 2, the domestic markets are growing, so IFDI increases, increasing the location advantages. This raises IFDI to higher levels while OFDI remains insignificant.
- In Stage 3, the country's technological capabilities will enable the production of standardised goods, wages will grow, and labour-intensive production will decrease. The country will be attractive for investments in producing technology-intensive products. Generally, IFDI flow will decrease while OFDI will rise significantly.
- Stage 4 is reached when IFDI and OFDI flow level off with each other and the growth of outward foreign direct investment is higher than the rate of increase of inward one. In this situation, domestic firms are strong enough to compete with foreign ones and penetrate foreign markets as well.
- In Stage 5, the net OFDI level will fall, and IFDI and OFDI will be more balanced (Dunning et al., 1993).



1. Figure: The investment development path

Own creation on the basis of Dunning and Narula (1993)

A critical update on the investment development path reviewed it by analysing the Central Eastern European (CEE) economies. Most of its findings are also valid in this context, but the institutional factors should be strengthened. OFDI can be enhanced if the country makes progress in the overall reforms, privatisation, restructuring, price liberalisation, competition policy, banking reform, etc. (Stoian, 2013). Dunning also introduced institutional factors into his research: "in a dynamic, complex and volatile global economy, the role of both firm and location-specific institutions in reducing the transaction costs of cross-border value-added and exchange activities is becoming more important" (Dunning et al., 2008).

Besides the five stages theory, the role of labour and the gravity models can provide a background for this study. The available labour force is an essential local factor for investment. Recently, however, the focus has been more on quality than quantity, as an investment is often initiated in high-tech industries. There is a "war for talent" in locations and industries that lack skilled workers. Therefore, the availability of a sufficient workforce is a factor with growing significance for foreign firms selecting a new location (Becker et al., 2020). This aspect is adequate to consider in the V4 region as these countries used to have high employment after the system change. Still, nowadays, they are facing a labour shortage as 1,5 million more people are working in the region than a decade ago (Szeiner et al., 2021).

The gravity model was initially applied to economics by Isard in 1954. According to his findings, the trade between two countries is proportional to their economy's size and distance (Capoani, 2022). A gravity model complemented for FDI shows that investments are indirectly proportional to distance costs (Paniagua, 2015), meaning that nearshoring[19] can be economically advantageous. The article also finds that the role of re-investors was neglected in FDI-related literature. Another study observed that FDI positively correlated with GDP and negatively with distance (Dorakh, A., 2020). The author also declared that EU membership resulted in 23% higher FDI inflows for newer member states between 1991 and 2017. The gravity model is particularly adequate to use when I analyse the possibilities of backshoring due to robotisation in the leading industrial economies.

2.1.2.2. Automation and FDI

Automation tendencies and technology development, in general, have an impact on foreign direct investment-related policies as well. The new manufacturing technologies influence leading MNEs to reconsider their investment strategies, and they might choose the scenarios of “retention”, “selection”, and “reconfiguration”:

- keep their existing manufacturing facilities and upgrade them by installing Industry 4.0 technologies,
- consolidate and concentrate manufacturing activities in specific locations,
- reshore part of the activities and establish new facilities or outsource specific tasks (Szalavetz, 2017).

From the abovementioned list, reshoring/backshoring is a pertinent topic nowadays, e.g., large MNEs headquartered in leading industrial countries might reconsider their investments in less developed countries. This threat is identified as scientists tend to agree that automation-related developments will be uneven geographically, e.g., that developed economies, especially the higher industrial ones, will benefit more than most of the developing ones. Spence and his co-authors argue that the developed world will be the ultimate winner of the current changes. “All these trends play to the strengths of developed countries, where skilled work forces, large quantities of capital, huge customer

[19] Nearshoring means relocation of investments to the home region and backshoring means the relocation of the offshored investments to the home country (Merino, et al, 2021). Backshoring is also often called reshoring.

bases, and dense clusters of high-tech companies combine to power modern economies." (Lund et al., 2019). They mention that some middle-income countries, such as China and Mexico, might catch up in the new era of globalisation, but many developing countries will face significant difficulties if they are not able to change from their cheaper labour-driven economic contribution. This finding aligns with the thoughts of automation experts (Atkinson, 2019). Accordingly, it is also noted that "the rapid development of the robotization and artificial intelligence in the last decade have helped the redirection of FDI flow from low-wage countries to higher-wage and more developed countries" (Kalotay et al., 2022). The same conclusion is reached by researchers investigating the issue with different methodologies (Suzuki et al., 2019; Cigna et al., 2022).

Robots also play a role in this process: more developed economies benefit more from automation tendencies as they already have a higher robot density and a higher stock of complementary traditional capital (Alonso et al., 2020). A World Bank study analysed the empirical results of robots used and their relation to OFDI to low- and middle-income countries between 2004 and 2015 (Hallward-Driemeier et al., 2019). The research used the fDi Market Database for the number of greenfield FDI projects and the statistics from the International Federation of Robotics (IFR) on the operational stock of robots for the period of 2003 - 2015. The authors' research questions were whether there is a slow-down in offshoring and if there are signs of reshoring to higher-income locations. Consequently, "the number of greenfield FDI projects from high-income countries to low- and middle-income countries can be expressed as a function of the sector-specific intensity of robot use in source countries".

The results show that the link is mainly positive (especially in middle-income countries), and in most cases, the stock of robots per 1,000 employees in developed countries increased together with the growth in IFDI in developing countries (from the developed ones). However, it was also noted that in approximately 25% of the sample, after reaching a specific density of robots used, the FDI flow from high-income countries to low-income ones starts decelerating. In 3% of the sample, the results indicated that a higher robotisation in leading industrial countries created a decline in foreign direct investment from high-income countries to low and middle-income countries. At the same time, the authors paid attention to the early warning signs as continued robotisation beyond a threshold level resulted in a slower-growing FDI in developing countries (Hallward-Driemeier et al., 2019).

An OECD working paper (De Backer et al., 2018) augmented the previously described paper. The flexibility of the production process was also vital for MNEs, allowing firms to satisfy consumer demand through quality increases and higher product customisation. They found that industries in emerging economies are generally not progressing in the same manner in robotisation as in highly developed countries. However, they also acknowledged that some emerging economies substantially invested in robotics due to a government strategy. This investment was set to compensate for the labour cost increase in these economies and compete with the developed economies. Regarding the relation between robotisation and offshoring for developed economies, their results were similar to those of the previous study. No significant link was found when investigating the whole period (2000 – 2014). However, the analysis of the last period of the analysed period (e.g. 2010 – 2014) indicated a negative association between robotisation and offshoring. According to them, a 10% increase in the robotisation stock produced a -0.54% rise in offshoring. Nonetheless, the strength of robotisation seems to be limited at the moment: it is enough to keep some production in highly developed economies but not strong enough to take production outsourced earlier to developing economies back to developed countries (De Backer et al., 2018). Another author (Butollo, 2021) goes further and acknowledges contradictory tendencies. He found that "technology .. does not have a one-directional effect on the geographies of production". Automation is also present in emerging countries, where production costs are lower. In this respect, nearshoring is a more realistic scenario than reshoring (Butollo, 2021). This finding particularly applies to my research as the Visegrad Four countries are also emerging economies with cost-efficient production possibilities.

An empirical study focusing on Europe revealed that "companies that use or intensively use industrial robots in their production processes relocate parts of their manufacturing activities less frequently outside the borders of the EU and Switzerland than companies that do not make use of industrial robots in manufacturing" (Kinkel et al., 2015). A follow-up research (Dachs et al., 2019) added that besides Industry 4.0, other factors might support backshoring in the future, e.g. increasing labour costs in offshore locations, the decreasing share of labour costs on total production costs and the vulnerability of global chains.

A German manufacturing industry-focused article (Kinkel, 2020) concluded that although companies still follow an internationalisation strategy, there was an increased focus on critical factors. While cost-based focused offshoring is declining, market-related expansions are emerging. These discoveries are supported by an article reviewing Swedish offshoring and backshoring examples (Johansson et al., 2018). They declared that the role of qualitative aspects had increased recently. While the offshoring investments of the examined companies were still based on the drive to improve cost performance, in the case of backshoring, other factors played an important part as well. These were the search for quality and flexibility-related advantages, such as access to skills and knowledge. Logistical factors were also crucial, as being close to the market offers the possibility for shorter and more reliable customer lead times (Johansson et al., 2018). In line with these findings, the primary motivation behind the backshoring activity of European companies is not to save on labour costs. Instead, the intention is to avoid the cost of non-conformance and increase performance (Ancarani et al., 2019).

As investment motives are changing from quantitative to qualitative ones, it is also relevant to consider the issue in the Visegrad Four context. The reasoning is that according to researchers (Éltető et al., 2022), the V4 countries are mainly considered as "assembly platforms" with low labour costs and tax benefits. If labour cost saving is no longer the main intention for an investment decision, then the presumption is that their positions weaken in the global investment competition. Thus, the question arises: is there any evidence for backshoring from these countries?

A study analysed the impact of automation on backshoring in the V4 context (Götz et al., 2020). According to the statistics, the number of backshoring activities from Visegrad to leading industrial countries were limited. Poland has the most significant number of cases: out of the fifteen backshoring moves from Poland, eight were due to the robotisation of the production facilities. On the other hand, as the study pointed out, automation might also play a positive role in investment decisions for the V4 regions. The same question was investigated in Hungary (Éltető, 2019). She has not found significant backshoring activity from Hungary; on the contrary, there were examples of nearshoring to Hungary from Asia. According to her, instead of backshoring, MNEs automatise their operations in Hungary to solve the labour shortage. Besides these factors, the beneficial tax conditions also play a role in keeping Hungary an attractive FDI destination (Éltető, 2019).

The positive and negative impacts of automation and digitalisation tendencies on the FDI flow materialise simultaneously: if the investors upgrade their existing firms in their outsourced location with new digital solutions, it naturally increases the efficiency of production in a certain country. However, if there is a decrease in their OFDI willingness, it has a reverse effect on the particular economy, which would be the target of the investment. The balance of the two effects is a function of the location advantages of a particular country (Szalavetz et al., 2019). For the reasons above, the technology spillover potential is vital for the FDI-receiving country, and to measure it, a spillover potential index was invented in a research study analysing the spillover effects of investments in the manufacturing industry of the Visegrad Four (V4) countries. The founding of the study is that MNEs should diversify their strategies in a region, and governments should vary their incentives towards MNEs (Szent-Iványi et al., 2012).

2.1.3. Technological upgrading

Innovation-related investments support the development of a particular company, industry or country. Robotisation is one of the manifestations of innovation-related activities in production processes. Therefore, the pace of robotisation alone can be seen as an indicator of development or, in other words, technological upgrading. This is underlined by the fact that robots are one of the critical drivers of productivity increase in developed countries (Atkinson, 2019).

A key organisation in the field of robotisation is the International Federation of Robotics (IFR). The IFR publishes annual statistics on the number of industrial and service robots[20] used at the country level. According to IFR, there are five main global trends in robotisation:

– artificial intelligence (AI) and machine learning,

- collaborative robots (cobots),

- mobile manipulators,

- digital twins,

- humanoid robots (IFR, 2024).

[20] Although service robots are important for the overall performance of a certain economy, in this research I rely on industrial robots only to keep the study focused on manufacturing.

The emergence of generative AI opens-up new possibilities for robotisation as well. Robots manufacturers build generative AI-driven interfaces allowing the teaching of robots with natural language. This eliminates the need for coding skills to program the robots. The other area where AI can give a boost to robotisation is the support in predictive maintenance. With the support of AI significant level cost sparing can be implemented in production lines (IFR, 2024).

Collaborative robots can support workers in raising, moving heavy objects, conducting repetitive actions and to work in dangerous environments. Currently, there is an expansion of the potential fields of application of cobots. For example the lack of skilled welders stimulates the spread of cobots in the welding sector (IFR, 2024).

Mobile manipulators are the combination of robotic platforms and manipulator arms. They can be used in complex environments and in object manipulation which are important aspects in production processes (IFR, 2024).

Digital twins are virtual replicas of the real-life systems. They can use the data from robots to perform simulations and predict outcomes. The benefit is that the experiments can be tested without physical implementation (IFR, 2024).

Recently, there was a significant development in the field of humanoids. The advantages of humanoids (equipped with two arms and two legs) that they operate easily in human-centred environments. The Chinese Ministry of Industry and Information Technology (MIIT) plans to start the mass-production of humanoids by 2025 (IFR, 2024). There is a recent example of employing humanoids in the automotive industry. Apptronik, the creator of 'Appollo' a general-purpose humanoid robot, teamed up with Mercedes to install humanoids in their factories. According to Apptronik: "..this approach centers on automating some physically demanding, repetitive and dull tasks for which it is increasingly hard to find reliable workers" (Apptronik, 2024).

Although these trends show cardinal changes in industrial processes, they are not explored in my study. Some trends are quite new, with a likely impact only in the future, whereas my centre of attention is on processes which were already significant in the twenty-tens. As described in the introduction, I considered robots in a broader category and investigating the various categories one-by-one was not feasible within the constraints of the current study. Nevertheless, these trends provided a useful background information for my analysis.

What is more interesting for this study, is what kind of impact the technological development makes on the economy? One angle to consider it is the effect on quality. As reported by a study (DeStefano et al., 2021) robotisation in developing countries had a positive implication, namely upgrading in quality. The authors recognised that robots can enhance export quality. Robots upgrade the quality especially in products where the quality was initially low. As these kind of products are more dominant in developing countries, "results suggest that developing countries may have greater potential for quality catch-up through automating their production" (DeStefano et al., 2021).

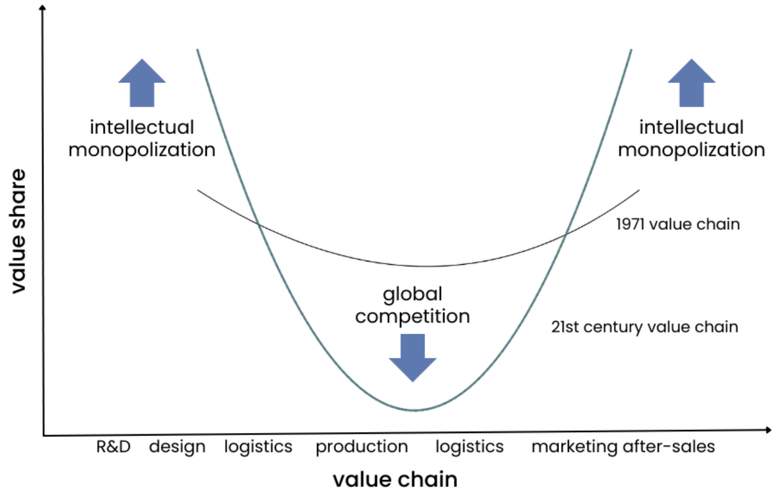
Decisions on deploying new technologies, like robots, are also affected by geographical factors. Analysing the effects in a sectoral and regional comparison, Krzywdzinski observed different labour-use strategies that firms deploy in highly automated plants. The location of the plan and the probability of having a lead role in implementing new technologies are strongly correlated. A survey found that 55 percent of German plants have a leading role in implementing modern technologies; in CEE, only nearly 23 percent of plants report having such a role (Krzywdzinski, 2017).

2.1.4. Upgrading in Global Value Chains

2.1.4.1. The development of GVCs

Global value chain (GVC) refers to the processes through which products undergo several value-enhancing international intermediate stages of transformation and combine with other inputs before becoming final (Buelens, 2017). The GVC analysis framework provides a holistic view of global industries on activities conducted in inter-firm networks on a global scale (Gereffi et al., 2011). GVCs are increasingly important globally (Antras et al., 2014), therefore I involve them in my research.

A crucial GVC-related foundation by Baldwin is the "smile curve" (Baldwin, 2013). He discovered that offshoring of production started during the second unbundling of globalisation. The value-added content decreased in the offshored stages. The smile curve (2. Figure) asserts that fabrication – especially final assembly – involves less value creation today than it did before the second unbundling – the smile deepened.." (Baldwin, 2013). Baldwin classifies the investors as "headquarter economies" and the recipients as "factory economies".



2. Figure: The smile curve: good and bad stages in the value chain

Own creation on the basis of Baldwin, 2013

During recent decades, it can be observed that there has been an ongoing offshoring process from developed countries to developing ones. The large MNEs relocate their production-focused functions to less developed countries, while they maintain control of higher value -added activities in their home countries (Neilson et al., 2014).

Participation in GVCs has several benefits. The increased participation in GVCs may lead to higher output, productivity, value-added and new jobs (Kummritz et al., 2017). Out of them, productivity growth is an important indicator, especially from the automation point of view. A study examining the role of GVCs in the economic upgrading of developing countries found that GVC integration can support productivity growth (Pahl et al., 2020). However, the authors also found that "relatively less productive countries can benefit more from GVC participation in terms of productivity growth" (Pahl et al., 2020). The reason is that the further a country is from the technological frontier, the higher the potential for productivity improvement. They affirm that there is no positive relation between employment growth and GVC participation (Pahl et al., 2020). This link may even turn negative in the manufacturing industry when developing economies reach their "productivity frontier". The potential reason is the labour-substitution due to automation (Xing et al., 2021).

When examining the role of global value chains in research, development, and innovation, it was recognised that foreign R&D expenditure through GVCs supports the production of ideas in the home economy. According to the study, in the short term, GVC participation increases innovation by 5% on average, and it grows by 3,5 times in the long term (Piermartini et al., 2021). Innovation activities and the location of these activities have growing attention in GVCs, and it is observed that: "While innovation processes are clearly embedded within GVCs, the spatial and sectoral boundaries of innovation systems are fluid" (Gereffi et al., 2019). There are different innovation trajectories within GVCs: gradually increasing, leap-wise increasing, stagnating, and declining (Lema et al., 2018).

One of the crucial aspects in GVC participation, to what extent can the certain subsidiary upgrade within the GVC? Upgrading within GVCs has many forms, including product upgrading, process upgrading, functional upgrading and intersectoral upgrading (Humphrey et al., 2002).

Upgrading is not always a result of earlier activities; it can also be a tool. Although digitalisation changes the location advantages, it is more straightforward to state the significance of the effect of lower labour costs on IFDI decisions. Nowadays, the positive evaluation of several other factors is needed for an investment decision. Therefore, compared to an earlier situation when foreign direct investment, new production processes and their spillover effects made upgrading possible, nowadays the tendency is more the opposite: the possibility to take part in more and new production processes by investors depends on the development/upgrading efforts of the particular economy (Szalavetz et al., 2019).

2.1.4.2. Robotisation and upgrading in GVCs

The examination of the effects of robotisation within the GVC framework is particularly interesting for my research. It was found that higher robotisation increases both employment growth and the value added in the particular industry. However, it is only beneficial for some participants; the advantages and disadvantages depend on which type of value-added component the certain industry is focusing on (Ghodsi et al., 2020).

Analysing the same issue at the country level, a study (De Backer et al., 2018) indicates that robot usage affects the upgrading possibilities of countries within GVCs. A higher level of robotisation might increase the efficiency and quality of production, which in turn might increase GVC participation.

2.2. Conceptualisation

In this sub-chapter, building on the literature review, I revisit the justification of the study's focus in the introduction. My explanation concentrates on the hypotheses: what are the underlying assumptions behind them?

2.2.1. Focus areas

As mentioned in the introduction chapter, automation, especially robotisation, is the independent variable in my research; I study its impact on the dependent variables.

The new disruptive technologies, for example, advanced automation technologies like artificial intelligence, are changing our world fundamentally, including the economy and the social and scientific systems (Kovács et al., 2021). Within automation, the "traditional" hard-coded automation is to be differentiated from artificial intelligence (AI) as the latter is closer to human beings than to hard-coded automation from several points of view (Gurály, 2022).

Automation is also taking place in the manufacturing industry, mainly in the form of robotisation. The sector is important due to its high share of exports and the positive spill-over role on other sectors (Tassey, 2014). Robots make operations quicker and more efficient, produce less waste and utilise the possibility for production 24 hours a day, seven days a week. Consequently, the use of industrial robots is growing; for example, the growth rate in 2021 was 31% (IFR, 2022)

In my analysis, I focus on physical robots only as they are closely linked to production, and also, they are better quantifiable. Besides, AI-related developments are accelerating, and their impact on production was less relevant during the last decade. In other words, AI is the future technology, whereas robots have already been part of the past.

The concentration on the manufacturing sector seems to be already justified by the robotisation-related analysis. Still, it also has a special significance in the V4 context as their manufacturing industry has outstanding importance, and experts label them as "industry-oriented factory economies" (Hillebrand, 2022). The time element is also crucial, many studies in the field is based on data which is ten years old or older (e.g. Hallward-Driemeier et al. 2019, Kinkel et al. 2015).

In terms of geography, I cover the V4 countries. As mentioned in the introduction, they provide a compelling basis for the analysis for several reasons. First, incoming foreign direct investment plays a critical role in their economies (Sass, 2021). Second, these countries had recently experienced significant technological development, mostly due to the investment of large multinational companies. Third, through the subsidiaries of multinationals, they are more and more integrated into global value chains. Fourth, as dependent economies, they are considered vulnerable, and therefore, the potential impact of robotisation on labour is particularly relevant.

When leading up my assumptions, I follow the order of the dependent variables mentioned above:

- foreign direct investment,
- technological upgrading,
- upgrading in global value chains,
- impact on labour.

The rationale behind the order is that FDI is a major determinant of economic progress in V4. These investments also foster technological upgrading, which might change the level of involvement and related positions in global value chains. Potential changes in FDI inflow, the higher level of robotisation, and the exposedness in GVCs might affect the quantity and quality of jobs in these countries.

2.2.2. Foreign direct investment

The FDI-related hypothesis is, as mentioned earlier, that the robotisation-related growth in the leading industrial countries has a negative impact on the foreign direct investments of the leading multinational companies in the manufacturing sector of the V4 countries.

Starting the related conceptualisation, it is interesting to explore why foreign direct investment is an important indicator, especially for the Visegrad Four countries. As mentioned in the literature review, the mainstream thinking among economists is that FDI generates economic growth. This link is mainly present in middle-income countries (Baiashvili et al., 2020), like the V4 ones. As GDP growth is a crucial element for these "catching-up" countries, a significant amount of incoming FDI seems to be inevitable to finance this growth. Additionally, these countries are considered to occupy a pre-mature position in Dunnings' investment development path (Dunning et al. 1993) according to some related studies (Kuzel, 2017; Endrődi-Kovacs et al., 2021). Therefore, it is crucial for these countries to maintain the same level of FDI inflow as earlier, especially in their manufacturing sector, which – as introduced earlier – has a significant position in their economies.

When considering the potential impact of automation on investments, the primary concern raised by scientists is that the leading industrial countries are the likely winners of the process (Lund et al., 2019; Atkinson, 2019). Consequently, narrowing down the issue to robotisation and the manufacturing sector, there is a threat that the increasing robotisation in the Western European factories might decrease the volume of investments to the V4 "factory economies". The theory behind this is that the role of lower labour cost, as one of the main location advantages of the Czech Republic, Hungary, Poland and Slovakia, might diminish as the production cost at home countries of leading "FDI-sending" countries decreases.

The result of the "equation" is not straight as, on the one hand, the quantitative analyses in the field provide an ambiguous picture both at a general (De Backer et al., 2018; Hallward-Driemeier et al., 2019) and at a V4 level (Éltető, 2019, Götz et al., 2020). Besides, as mentioned earlier, although the related studies are relatively recent, the dataset from which they were composed is often older than ten years, and in automation and robotisation, the developments have started nowadays. Accordingly, I reason that there can be already signs of backshoring or at least a drop in the volume of investments in the manufacturing sector of the V4.

2.2.3. Technological upgrading

The technological upgrading-related hypothesis is as follows: Global technological advancement supports the technological upgrade in the V4 countries, mainly through the subsidiaries of large multinational companies. My related assumption is that as there is global technological progress, the whole world benefits from it, especially those in a "catching-up" position. Multinational companies bring new technologies to their subsidiaries via the GVCs, consequently supporting technological upgrading. According to Atkinson, robots are the key drivers of productivity increase in developed countries; my supposition is that the V4 countries as catching-up countries are alike in this respect. Thus, I presume that the increasing robotisation in the subsidiary factories of large multinational companies in the V4 is one of the drivers of technological upgrading.

2.2.4. Upgrading in Global Value Chains

The hypothesis for the GVC-related upgrading is specified below: The technological development in the subsidiaries of the large multinational companies in the V4 promotes upgrading these units in the Global Value Chains. My argument is that the above-mentioned technological upgrading is linked to boosting GVCs in both ways. First, as mentioned above, new technologies arrive at the V4 subsidiaries mostly via the investments of multinational companies. Therefore, GVC participation can support technological upgrading. Second, once there is a technological improvement (e.g., new robots, assembly lines installed, new production methodologies implemented, etc.), it provides a basis for taking over more complex activities within the GVCs. Consequently, I assume that the V4 countries can climb upwards on Baldwin's curve by building on their improving technological and knowledge base.

The expectation was to measure the progress towards the "left" on the curve, e.g., activities preceding production (e.g., research and development, product design, production-related innovation, etc.), as the right side (e.g., logistics, marketing, etc.) is not directly related to manufacturing-related robotisation[21].

2.2.5. Jobs

The hypothesis on the job-related impacts is that the increase in the level of robotisation in the manufacturing sites of multinational companies in the V4 region has an impact on the number and type of workers employed.

The first possible impact is due to the increase in the number of robots in the major "FDI-sending" countries. The growing rate of robotisation in leading industrial countries is a well-known issue,[22] and it might change the investment landscape in the manufacturing industry. My related premise is that this kind of automation decreases the production costs at the home economies fundamentally, especially in the Western European headquarters, where the salaries are significantly higher than in developing or even in V4-like developed countries, which can be considered as "catching-up" ones. If, for example, a German automotive company can decrease the production costs in their home factories

[21] There are signs of a progress of activities on the rights side as well, however the participation in shared service centres, involvement in logistic centres are related to other factors and not to the impact of robotisation.

[22] The already mentioned IFR produces underlying statistics.

substantially, the motivation to outsource these activities might shrink, and consequently, the number of staff employed in the subsidiary factories will decline.

The other likely impact is due to the increased robotisation directly in the V4 factories. As the production processes become more automated in these locations, manufacturing requires fewer human interventions, therefore the headcount might drop.

Third, the kind of jobs established in these countries also relates to the hypothesis. My consideration is that multinational companies create an increasing number of skilled and office jobs at the expense of the simple, unskilled manual ones at the assembly lines.

3. EMPIRICAL ANALYSIS

As explained in the Theoretical Framework chapter (chapter 2), in this chapter, I analyse the impact of robotisation on the four dependent variables:

- foreign direct investment,
- technological upgrading,
- upgrading in global value chains,
- impact on labour.

3.1. Foreign Direct Investment

In this section, I analyse whether the robotisation-related growth in the leading industrial countries has a negative impact on the foreign direct investments from the leading multinational companies in the manufacturing sector of the V4 countries.

3.1.1. Analysing the potential impact of robotisation on investments in general

The first compelling question is whether a general link between increased robotisation and changes in the magnitude of investments can be realised. I find the leading industrial countries particularly interesting in this respect, as they are the largest investors in the manufacturing sector through their large multinational companies.

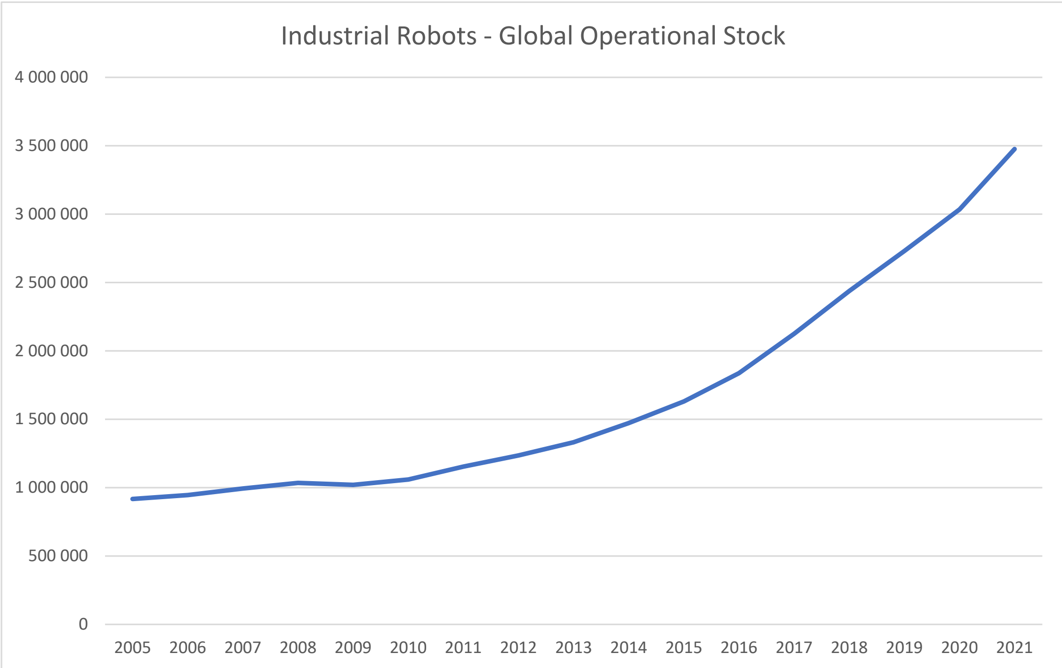
One aspect to consider is how technology development advances in these leading developed industrial countries. As revealed in the introduction and the methodology section, I use the number of industrial robots as an independent indicator in my analysis. The changes in robotisation represent technology-related development, in other words, the technology upgrading[23] tendencies.

Therefore, I analysed the differences in the rate of robotisation in different leading industrial countries and identified the main relevant tendencies. For this work, I used the International Federation of Robotics database (IFR, 2023a).

[23] In my study I differentiate technology upgrading from GVC-related upgrading. Although the two are linked, they are not necessarily correlated. The increase of the number of robots for example in a country, alone, does not necessarily mean the upgrading in the global value chains.

IFR has two databases in the robotics field, one focusing on industrial robots and the other on service robots. For my work, the first is relevant[24]. The data shows the robotisation stock on an annual basis by country[25]. IFR covers the global market as it has access to nearly all the robot producers of the world (IFR, 2022).

The chart below shows that the robotisation stock is expanding substantially (3. Figure). What is also considerable is that, in addition to the volume growth, the growth rate has accelerated[26].



3. Figure: Operational stock of industrial robots worldwide

number of units (IFR, 2023a)

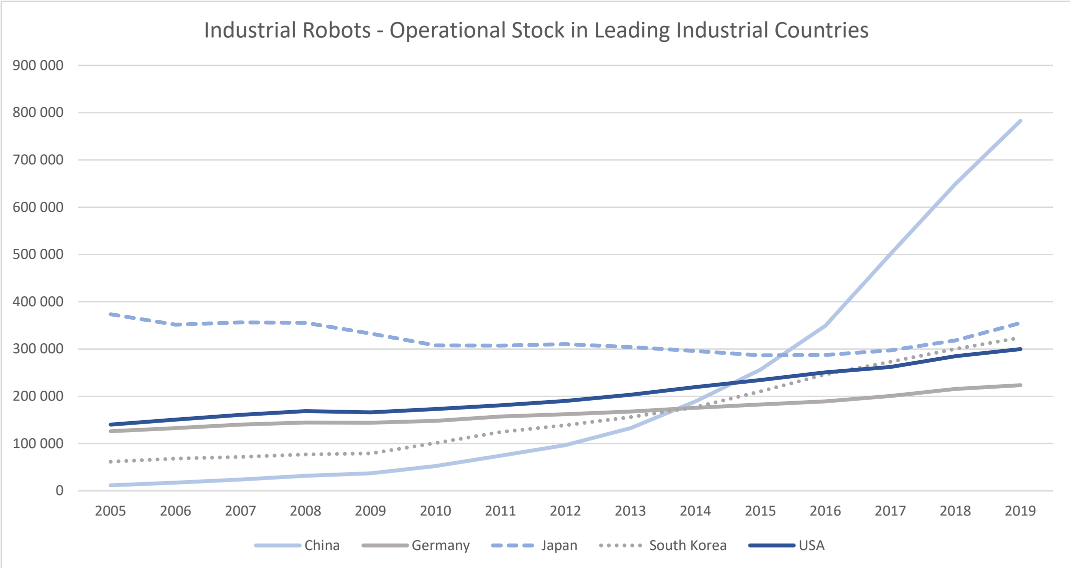
The global distribution of robots is not even; there is a high concentration: the five most robotised countries held 73% of the total industrial robots in use in 2019 (own calculations on the basis of IFR, 2023a). These leading industrial countries are in the order of position in the number of robots used: China, Japan, South Korea, the USA, and Germany. As presented in the figure (4. Figure) below, the growth tendencies and the positions show a

[24] A part of the service robot portfolio is indirectly linked to manufacturing, e.g. robots used in logistics and warehousing, however in order to keep the research focused, the usage of industrial robots statistics is more appropriate.

[25] According to the database available for researchers, IFR has other classifications within their products.

[26] The concrete numbers and the growth rate changes can be found in a table in the Appendix (Appendix A).

significant variation over time[27]. China grew from a marginal role to an absolute leader in industrial robotisation in fifteen years. Germany maintained a moderate growth rate, while Japan was the only leading robotised country, with a stagnant number of robots.



4. Figure: operational stock of industrial robots in the five main robotised countries number of units (Based on IFR, 2023a)

To complement the trends set by the absolute values, it is worth mentioning that the relative values show a different perspective. Considering the robotisation rate per manufacturing worker, South Korea ranked as the leader, followed by Singapore and Germany in 2017 (Guraly, 2020).

When selecting the dependent indicator for the analysis, e.g. the FDI-related one, the outward foreign direct investment stock appeared as the rational choice. It is a widely used indicator, and it has been available for many countries for a relatively long period (OECD, 2023). However, as my research focused on the manufacturing industry, I found OFDI too general for the purpose, as it also included investments in several other sectors. Therefore, I searched for an indicator more related to the tendencies in investments in the manufacturing sector. The outward foreign direct investment stock to the manufacturing industry was an adequate factor for considering the geographic effects of robotisation. The assumption was that a higher level of robotisation in leading industrial countries could make production in the home country more profitable. Consequently, it might decrease the motivation to invest abroad. For that reason, I used the OECD (OECD, 2023)

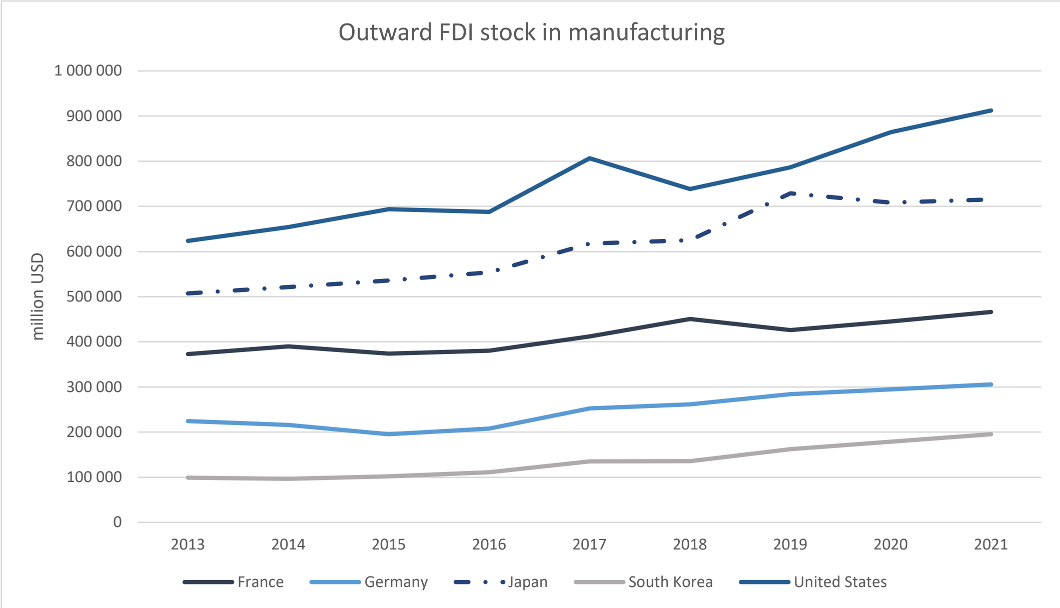
[27] Detailed robotisation data is available up to 2019.

outward foreign direct investment stock to manufacturing (MOFDI) to measure that "other end" of the equation, e.g. the impact of robotisation. Stock data was used instead of flow as it was more beneficial to predict tendencies; the volatility was much lower in these data.

The country selection for the analysis was based on the following two essential factors: data availability and relevance. In terms of data availability, the robotisation-related analysis earlier had already identified the five most relevant industrial countries. China was not classified as a developed country, and there was no data available for MOFDI in China. Therefore, China was excluded from further analysis. Notwithstanding, the other four leading countries in robotisation, Germany, Japan, South Korea, and the USA, were considered. As the main trading partners of the V4 countries were the EU member states, the most significant investing countries in terms of MOFDI were included, e.g., Austria, Belgium, Denmark, Italy, France, Spain and Sweden. The Netherlands had to be excluded from the list because its OFDI numbers showed high volatility[28], especially in 2020 and 2021.

The following chart (5. Figure) presents the outward foreign direct investment stock to manufacturing in a million US dollars from the eleven selected countries. It can be observed that the total MOFDI stock gradually grew in the investigated period and that, except for Denmark, the MOFDI stock at the country level was significantly higher in 2021 than in 2013. Accordingly, I can immediately exclude the assumption that growing robotisation in developed countries has a negative impact on outward foreign direct investment stock to manufacturing in *absolute* numbers.

[28] As mentioned later, OFDI data is used to show the changes of the relative share of MOFDI. Therefore, the substantial, outstanding changes in the volume of OFDI for one country – which can be a result of one or few large transactions – might distort the presentation of the overall tendencies.



5. Figure: Outward foreign direct investment stock in the manufacturing industry of the five largest from the eleven[29] selected countries (million USD)

Own creation based on OECD, 2023[30]

Nonetheless, the abovementioned finding can be misleading as most of the examined period was an era of growth (Eichengreen, 2018). Hence, a decrease in investments in absolute numbers is beyond expectations. Therefore, it was more accurate to consider the *relative* changes, e.g. comparing the MOFDI values with the OFDI ones.

The total outward foreign direct investment stock values calculated for the eleven countries for the same period also increased, as noticed in the manufacturing-related outward FDI values (5. Table).

million USD	2013	2014	2015	2016	2017	2018	2019	2020	2021
MOFDI total	2 419 423	2 433 703	2 458 877	2 478 311	2 845 051	2 835 308	3 036 915	3 156 330	3 320 653
OFDI total	12 866 186	12 718 141	12 453 795	12 953 165	15 467 163	13 942 579	15 720 080	16 895 384	18 471 368

5. Table: total MOFDI and OFDI for the eleven considered countries values in millions of USD (Own creation based on OECD, 2023[31])

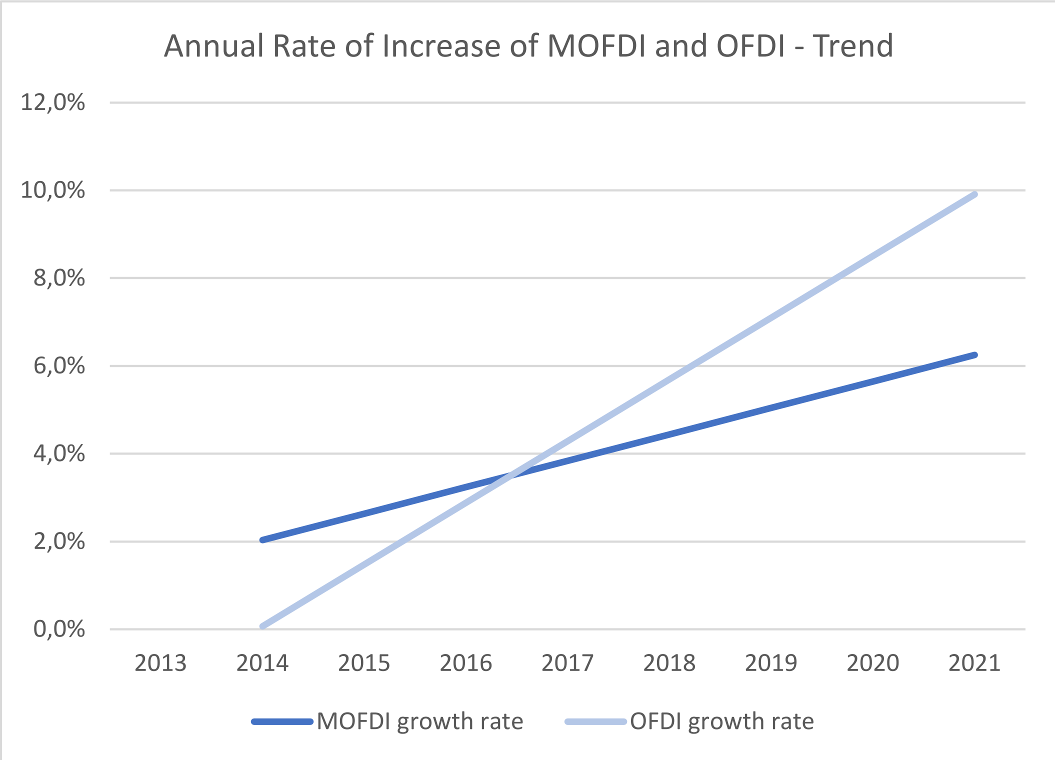
What could be recognised is that despite using stock data, there is significant volatility in the values of the different years. Consequently, instead of calculating the MOFDI/OFDI

[29] The table with the values of all the eleven selected countries can be found in the Appendix.

[30] Values highlighted with grey mean that there was no original data available therefore these values were extrapolated with the help of the two preceding or successive data.

[31] The detailed OFDI values for the countries can be found in the Appendix.

ratio, I figured out the individual growth rate within each variable compared to the previous year. Once I had these ratios, I applied the Trend functions of Excel[32]. The chart below shows the results (6. Figure). The graph depicts that although both the MOFDI and OFDI stock were increasing, the OFDI-related growth rate was significantly higher than the MOFDI rate.



6. Figure: MOFDI/OFDI increase rate comparison

The trend value of the annual rate of increase of the sum of the outward FDI stock to manufacturing and the trend values of the sum of the outward FDI stock of the eleven considered countries (based on OECD, 2023)

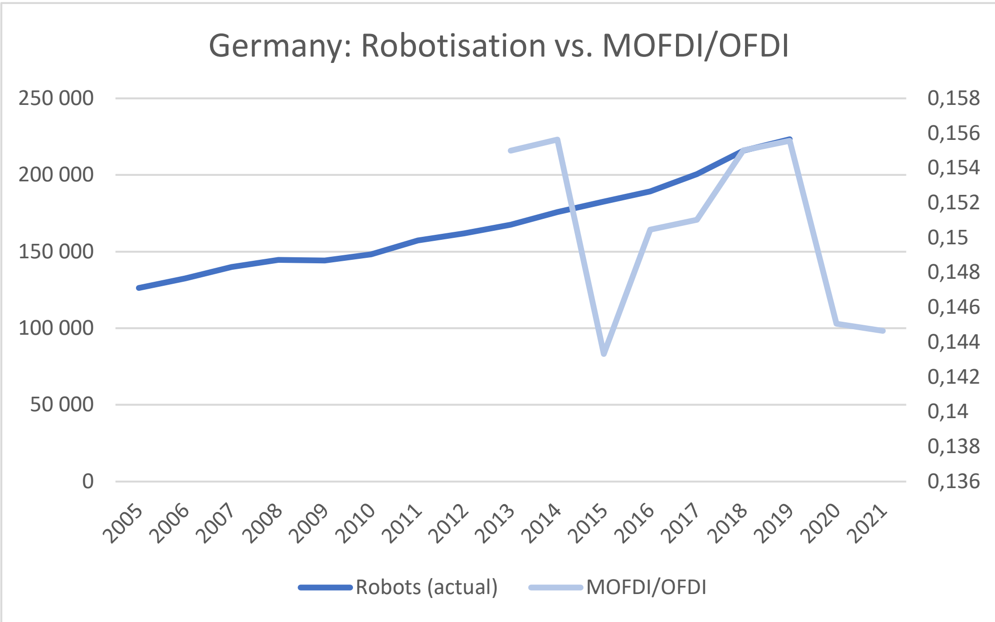
The finding was that the outward FDI stock to manufacturing was growing slower than the total outward FDI stock in the selected developed countries, which provided a basis for further quantitative macro analyses on the possible effects of robotisation on foreign direct investment.

Building on this finding, I investigated the possible link between robotisation and the outward FDI stock in manufacturing at the levels of selected countries. First, I analysed the trends of the most robotised countries in the selection and then performed a regression analysis for the eleven countries.

[32] The Appendix contains the relevant tables.

With the absence of data for China, the analysis at an individual country level was carried out for two of the other four most robotised countries, namely Germany and South Korea and as a comparison for France[33]. As mentioned earlier, while robotisation data was available for the period 2005 - 2019 for the selected countries, MOFDI data was accessible for the period 2013 – 2021 for most of the countries. Therefore, the intersection for investigation was the period 2013 – 2019.

While the actual numbers for robotisation (number of industrial robots in use) showed a continuously increasing curve for Germany, the ratio of outward FDI stock to manufacturing vs the outward FDI stock was unstable (7. Figure). Therefore, the possibility of drawing conclusions was limited.



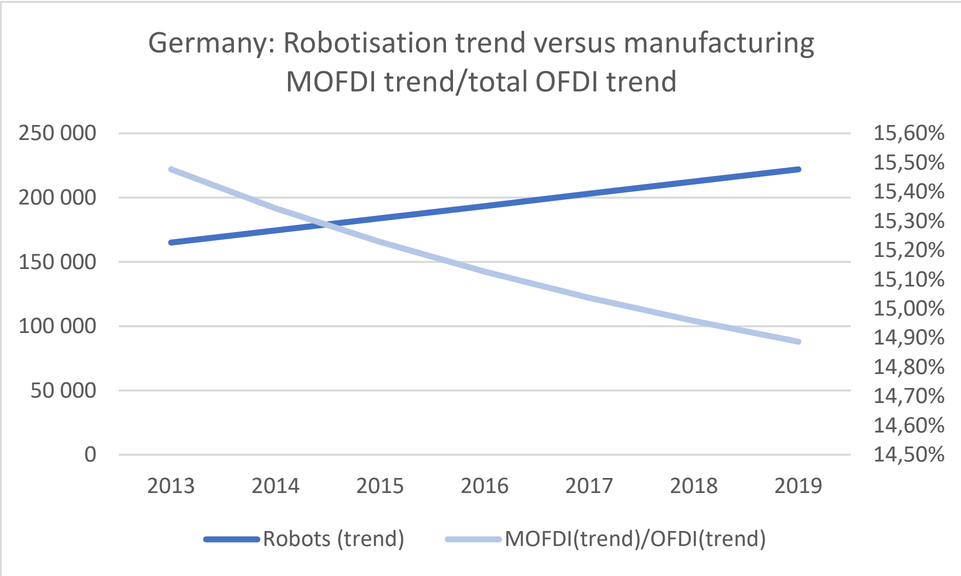
7. Figure: Robotisation vs. MOFDI/OFDI stocks in Germany

Comparison of the German robotisation stock with the ratio of MOFDI and OFDI stock

Own calculation based on IFR, 2023a and OECD, 2023

Due to the abovementioned difficulties, I applied trend (using the trend function of Excel) data for the robotisation stock and the MOFDI/OFDI ratio. The results are shown in the chart below (8. Figure). On this chart, the negative relationship is recognisable; for example, an increase in robotisation stock indicates a decrease in the share of outward FDI stock to manufacturing within the total FDI stock.

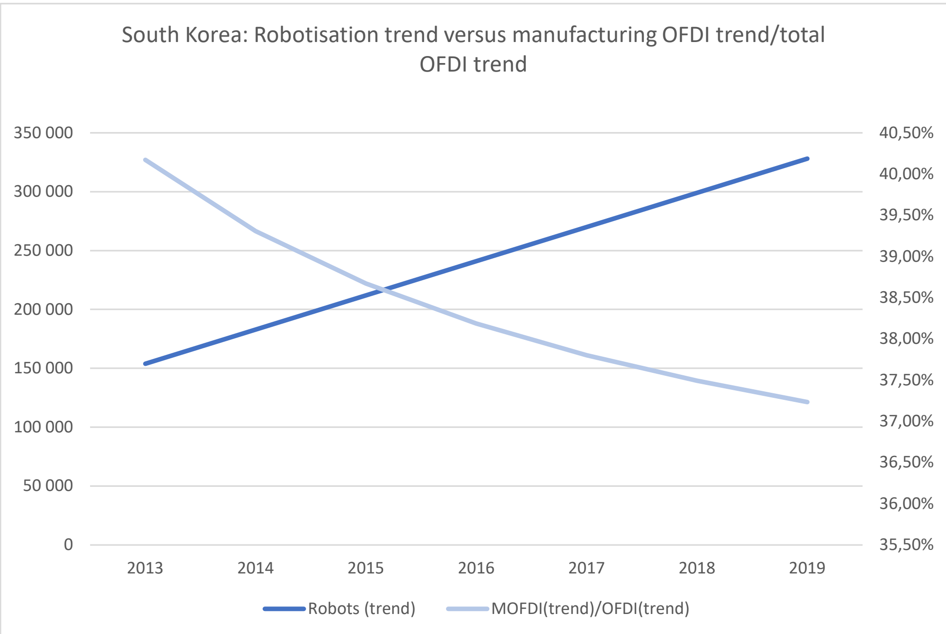
[33] The input tables for the analysis are in the Appendix.



8. Figure: Robotisation vs. MOFDI/OFDI trends in Germany

Comparison of the German robotisation stock trend with the ratio of MOFDI stock trend and OFDI stock trend (Own calculation based on IFR, 2023a and OECD, 2023)

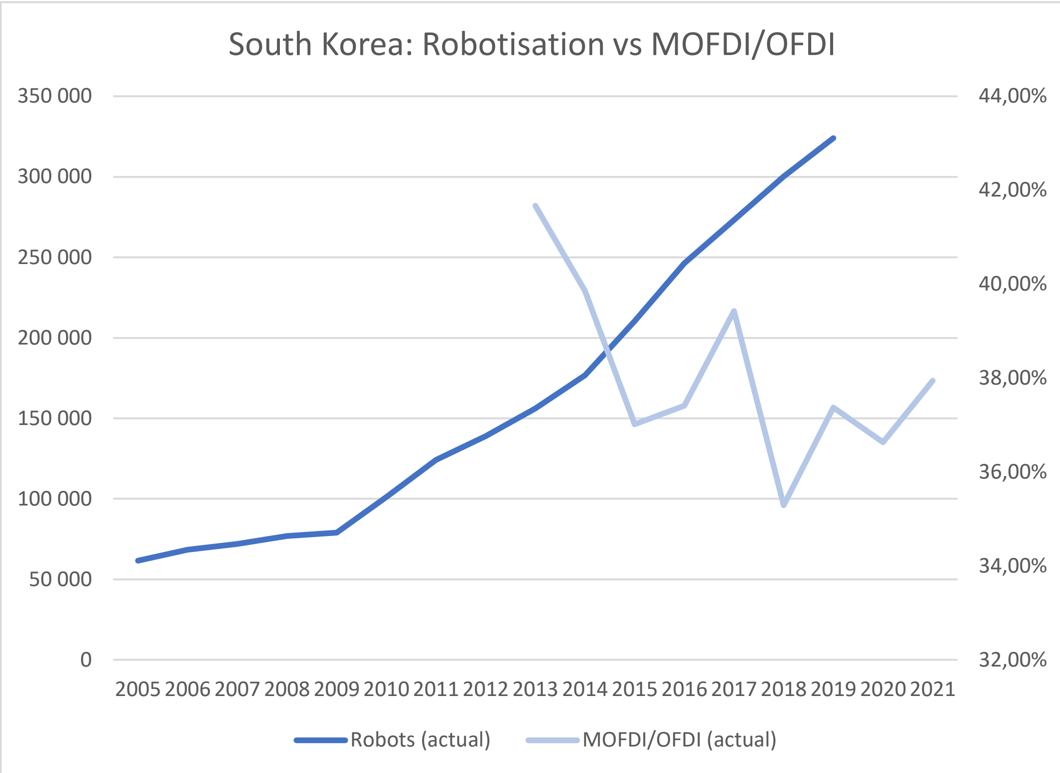
In the case of South Korea, the trend data shows an even stronger negative relationship as even larger negative percentages are present along with a higher increase in robotisation numbers (9. Figure)



9. Figure: Robotisation vs. MOFDI/OFDI trends in South Korea

Comparison of the South Korean robotisation stock trend with the ratio of MOFDI stock trend and OFDI stock trend (Own calculation based on IFR, 2023a and OECD, 2023)

However, trend data should be handled with care, as similarly to Germany, trend data differs significantly from actual data (10. Figure). In the case of robotisation, the trend is directly related to the actual data in South Korea and most of the other selected countries. Still, high volatility can be recognised with the MOFDI/OFDI stock ratio with actual numbers.

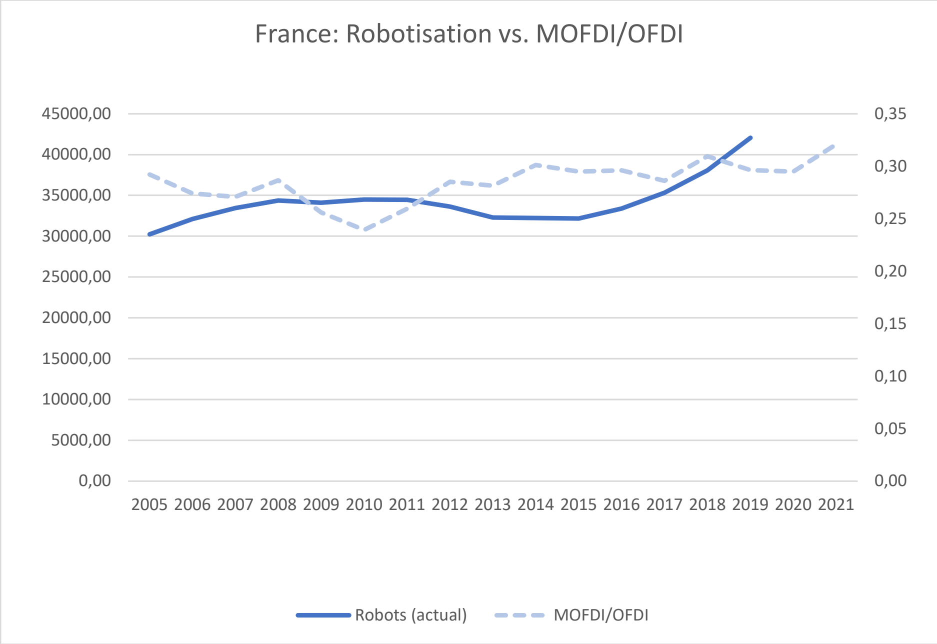


10. Figure: Robotisation vs. MOFDI/OFDI stocks in South Korea

Comparison of the South Korean robotisation stock with the ratio of MOFDI stock and OFDI stock

Own calculation based on IFR, 2023a and OECD, 2023

France is not among the top five most robotised countries. Still, it was interesting to consider it as it possesses the largest MOFDI stock in the European Union. Besides, for France, there has been MOFDI data available since 2005, so a more extended timeframe could have been considered. As shown in the chart below (11. Figure), a negative relationship could not be observed in the case of France.

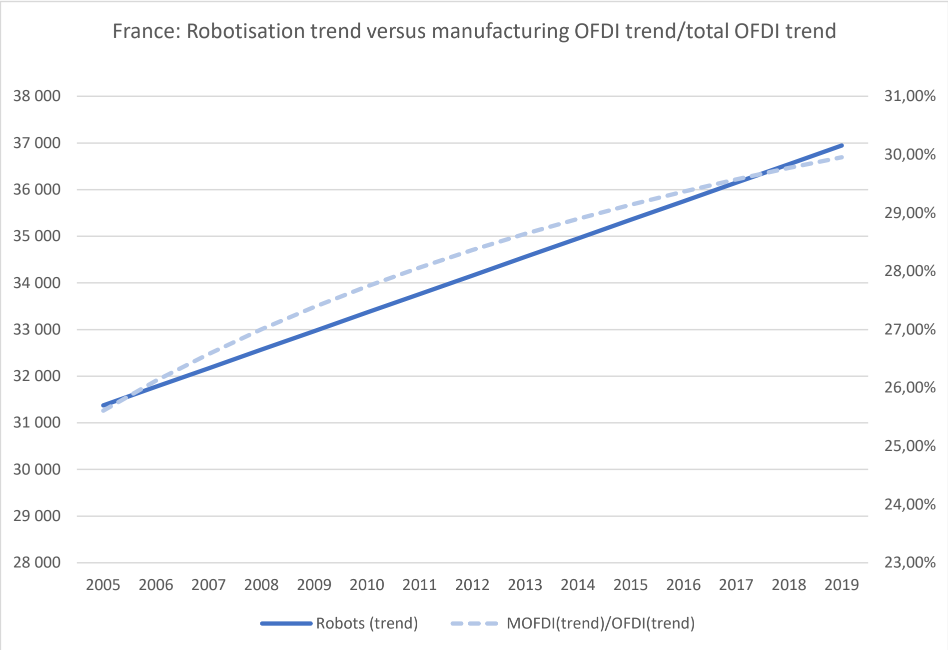


11. Figure: Robotisation vs. MOFDI/OFDI stocks in France

Comparison of the French robotisation stock with the ratio of MOFDI stock and OFDI stock

Own calculation based on IFR, 2023a and OECD, 2023

The link becomes more apparent when considering the trend data: robotisation and MOFDI/OFDI stock ratio are presented conjointly (12. Figure).



12. Figure: Robotisation vs. MOFDI/OFDI trends in France

Comparison of the French robotisation stock trend with the ratio of MOFDI stock trend and OFDI stock trend

Own calculation based on IFR, 2023a and OECD, 2023

As the individual country analysis provided an ambiguous result, I performed a regression analysis (with SPSS) involving the eleven earlier selected countries. The joint (panel) regression analysis was, on the one hand, more suitable as it provided more generic results, but also necessary on the hand, as the short intersection of the time intervals between robotisation and MOFDI data (2013 – 2019) provided only seven values per country what was too low for regression analysis. In the regression analysis, the independent variable was related to the robotisation stock in the selected countries. In contrast, the dependent was the ratio of the MOFDI stock and the OFDI stock in percentages. As there was a substantial difference between the robotisation stock values of the different countries (as already described earlier), the nominal robotisation value would have distorted the analysis. Therefore, I used the rate of increase compared to the first year (2013) in robotisation as the independent variable[34].

The sample size was 77 (seven years for eleven countries). The model was significant as

$F(12, 64) = 136.865$ $p < .001$.

Also, the R Square result was high, showing a strong relationship between the applied model and the dependent variable (6. Table).

Model related indicators	Result
Sample size	77
F value	0,000
Significance	Significant
R Square	0,962
Adjusted R Square	0,955

6. Table: Model-related results of the regression analysis[35]

However, the other results are negative for the analysis, as presented below. One critical outcome is that the significance (P) value is larger than the threshold (0.05) in the case of the main independent variable, the growth rate in robotisation for all the eleven investigated countries (7. Table). This means that the null hypothesis of the regression analysis is true, e.g. that I have to reject the assumption that there is a statistically significant, in other words, generic, correlation between the growth in the robotisation rate and the ratio of outward FDI stock to manufacturing and the total outward FDI stock

[34] The table with the input data can be found in the Appendix.

[35] The SPSS generated results are in the Appendix.

controlling for the year and the country as variables. This outcome is also shown in the results of the correlation analysis (7. Table), as according to the Pearson Correlation result, the relation between the dependent variable (MOFDI/OFDI stock) and the primary independent variable (Robotisation growth) is lower than 0.2. It is even close to zero, meaning that there is no correlation.

Robotisation growth related results	
Significance	0,396
Pearson correlation	0,031

7. Table: The dependent variables related results[36]

The finding is that although some relation was observed between robotisation and the relative changes in MOFDI stock with trend analysis within the individual countries, a generic, standardisable relationship was not found. The reason behind this is that, as already seen in the trend analysis, the trends between the two variables are different for the investigated countries.

As with all analyses, my regression analysis has limitations. Probably the main one is the data availability. Although I tried to specify the outward foreign direct investment stock further by using OFDI to manufacturing (MOFDI), this specification was probably not accurate enough. In the MOFDI data, all the outward FDI to manufacturing is presented, for example, in the case of Germany, both the MOFDI to Pakistan and the Netherlands. According to my initial assumptions, higher robotisation in the headquarters factories of German multinational companies might have a negative impact on investments in Pakistan but probably have no effect on investments in the Netherlands. Unfortunately, there is no available data set which would allow me to conduct a geographically selected MOFDI- related calculations.

More interesting is to cross-check this finding with former studies in the field. According to my examination, my finding aligns with the literature in the field. For example, Hallward-Driemeier and her co-author (Hallward-Driemeier et al., 2019) discovered that the link between robotisation stock in developed countries and incoming investment in developing countries is mainly positive[37].

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[36] The SPSS generated results are in the Appendix.

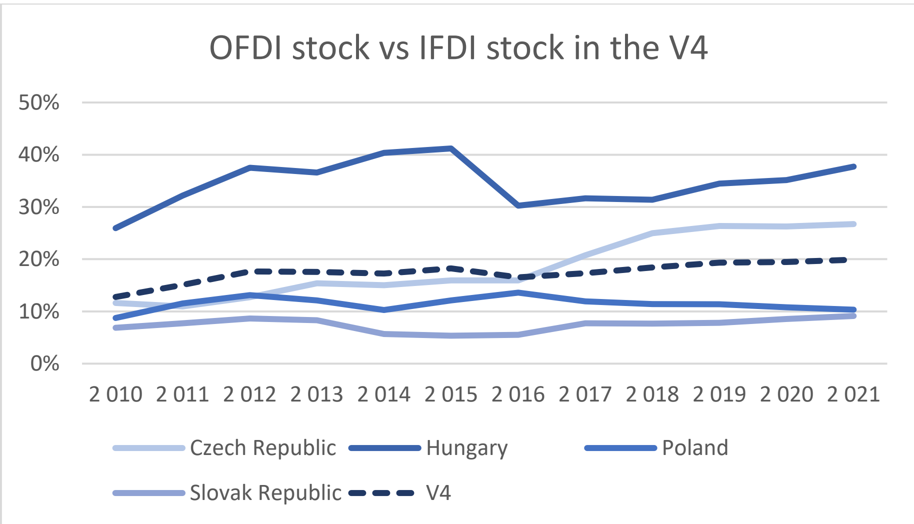
[37] As indicated in the literature review section.

Other researchers (De Backer et al., 2018) realised some negative effects of robotisation on investments, however, they found the related "power" of robotisation is still limited. It might help to sustain production activities in the leading industrial countries, but it is not yet strong enough to initiate backshoring.

3.1.2. Backshoring tendencies in the V4

Before I investigated the potential backshoring trends from the V4 due to robotisation in the home economies of multinationals, the first item to consider was the maturity of the V4 economies in terms of foreign direct investment. In the examination, I followed Dunning's investment development path model (Dunning et al. 1993). This model helped to identify the maturity of economies with the comparison of outward and inward FDI.

Therefore, I compared the outward (OFDI) and inward (IFDI) foreign direct investment stock values of the V4 countries (13. Figure). What is visible is that there was an increase in the ratio in the case of Hungary and, to a lesser extent, in the case of the Czech Republic, in the ratio of OFDI stock versus IFDI stock. The corresponding values of Poland and the Slovak Republic show signs of stagnation. What is more important is that the values are low, below 40%, even in the case of Hungary, possessing the highest value[38].



13. Figure: OFDI/IFDI in the V4

The ratio of outward foreign direct investment stock to inward foreign direct investment stock in the Visegrad Four countries (Edited by the author based on OECD data (OECD, 2023))

[38] This high value is partly a result of regional redistribution of FDI, so the real domestic originated OFDI is probably lower (Klauda, 2022).

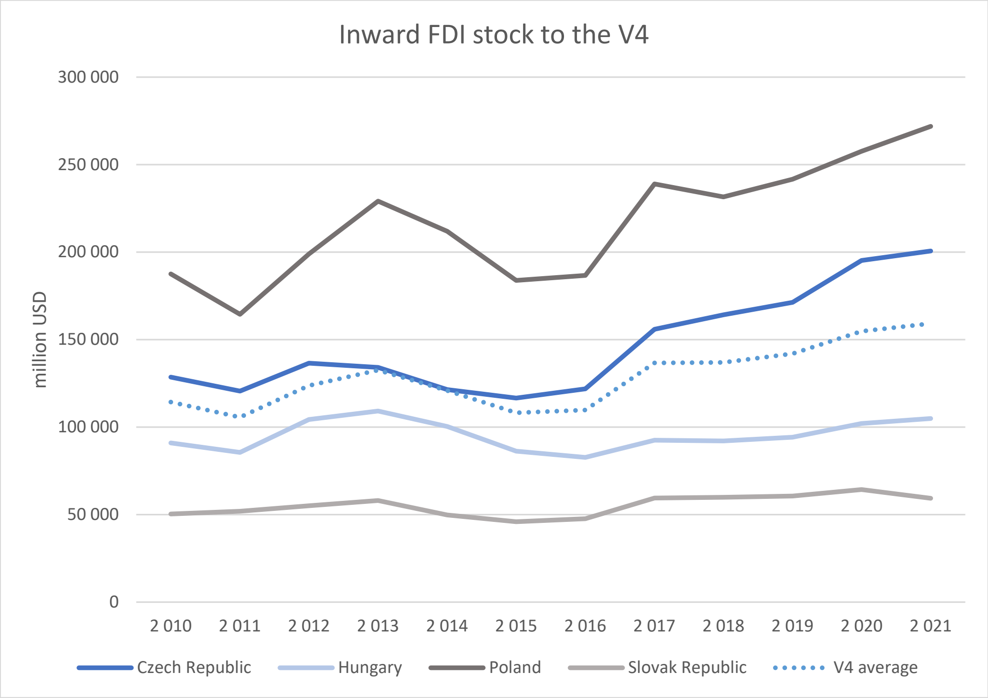
Consequently, my finding is that the V4 countries are at the beginning of stage 3. As mentioned in the literature review, stage 3 means that the technological capabilities in the country will enable the production of standardised goods, wages will grow, and labour-intensive production will decrease. This classification is backed by the quantitative analysis, the interviews conducted during my research, and some studies in the field (Kuzel, 2017; Endrodi-Kovacs et al., 2021).

These results indicate that the V4 economies are still relatively immature in terms of the balance of FDI. Although they are definitely developed economies, they are still on an evolving path and can be considered as "catching-up" economies towards the leading industrial countries. It is still an open question whether this gap can be closed and, if yes, when the catch-up process will be finished. What is more relevant for my research is that the outcome of this analysis indicates that the V4 is still very dependent on foreign direct investment; foreign capital is needed to finance the development of these economies. Therefore, if robotisation in the leading industrial countries has a negative impact on investments in other countries, that might have severe consequences on the V4 economies.

Although I did not find a general negative correlation between the changes in robotisation in the leading industrial countries and the level of outward investment in manufacturing from these countries in the previous section, this does not undoubtedly mean that such a link cannot exist in certain cases. Consequently, I consider the analysis of the investment trends in the manufacturing sector of the V4 countries appropriate.

When investigating the impact of robotisation on the V4 countries, I used inward foreign direct investment stock data as a dependent variable. As these countries are highly reliant[39] on inward foreign direct investment, this variable was adequate to measure the effects of the global robotisation trends on these economies. The inward foreign direct investment (IFDI) stock increased during the investigated period for all four countries (14. Figure). As presented in the chart below, there was growth in the IFDI stock in the region, although some unsteadiness can be seen in specific years for each country. The average growth trend-wise was around 4% during the period, albeit the annual growth rate shows a slowing tendency.

[39] The dependency theories were buttressed up in the literature review section.



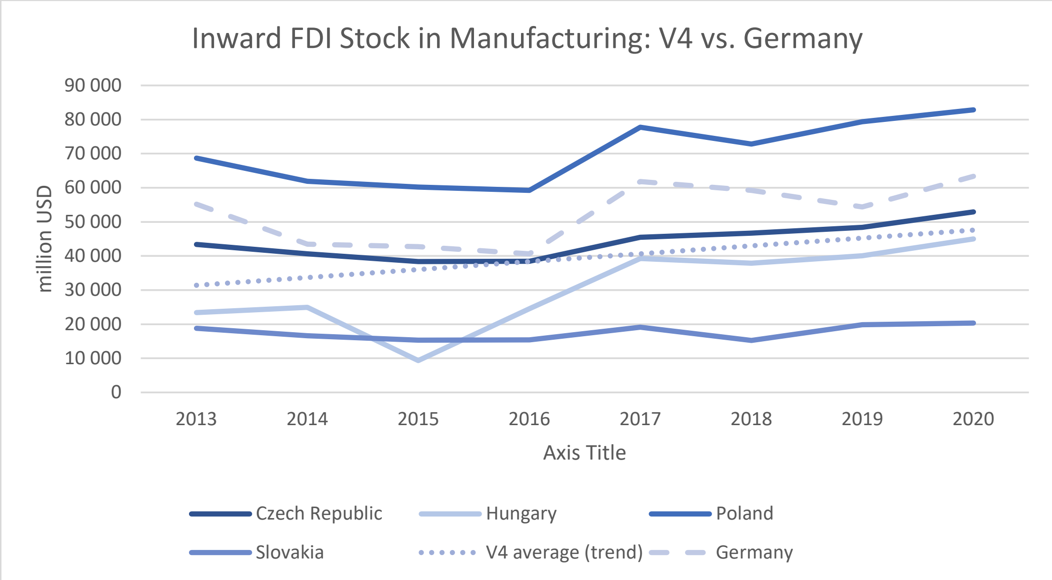
14. Figure: IFDI stock in the V4

Inward foreign direct investment stock in the Visegrad Four in a million US dollars during 2013 – 2021

Own creation based on OECD data (OECD, 2023)

The inward foreign direct investment stock in manufacturing (MIFDI) is more relevant from the manufacturing industry's point of view. The following chart details the MIFDI trends in the Visegrad Four in absolute values (15. Figure). The ranking of the countries in terms of MIFDI stock values corresponds to the order in population[40]. Germany is also presented in the figure as a benchmark. The high FDI-absorbing status of the V4 economies is grounded by the fact that Poland outperforms the twice more populous Germany in terms of MIFDI stock values. As the average trendline for the V4 countries indicates, the MIFDI stock growth was continuous and did not lag behind the related German growth rate.

[40] Tables displaying the population numbers and the MIFDI values per capita are presented in the Appendix.



15. Figure: MIFDI stock in Germany and V4

Inward FDI stock to the Manufacturing Sector in the V4 countries and Germany (million US dollars) from 2010 to 2020 (Own creation on the basis of OECD statistics, OECD, 2023)

In the next step, I compared the increase of the inward FDI stocks (both the total and the ones to the manufacturing industry) of the V4 countries with the rise of outward FDI stocks (also on both levels) of the earlier selected eleven leading industrial countries (Austria, Belgium, Denmark, France, Germany, Italy, Japan, South Korea, Spain, Sweden and the USA). According to the comparison (8. Table), while the OFDI-related growth of the eleven countries was higher than the rate of increase in IFDI in the V4, the relevant MOFDI and MIFDI values are roughly equal to each other. This means that the countries in the V4 group are utilising the possibilities for investments in the manufacturing industry from the leading industrial developed countries.

Rate of Increase 2021 vs 2013	Selected	V4
OFDI vs. IFDI	44%	20%
MOFDI vs. MIFDI	37%	38%

8. Table: OFDI/IFDI and MOFDI/MIFDI comparison

Rate of increase of the eleven selected countries in terms of OFDI stock and MOFDI stock versus the IFDI stock and MIFDI stock-related growth rate in the V4 (Own creation based on OECD statistics, OECD, 2023)

Additionally, the calculation of the ratio of the inward foreign direct investment to manufacturing stock and the total inward foreign direct investment (MIFDI/IFDI) in the V4 shows that the relative share of MIFDI is growing in the investigated period (9. Table).

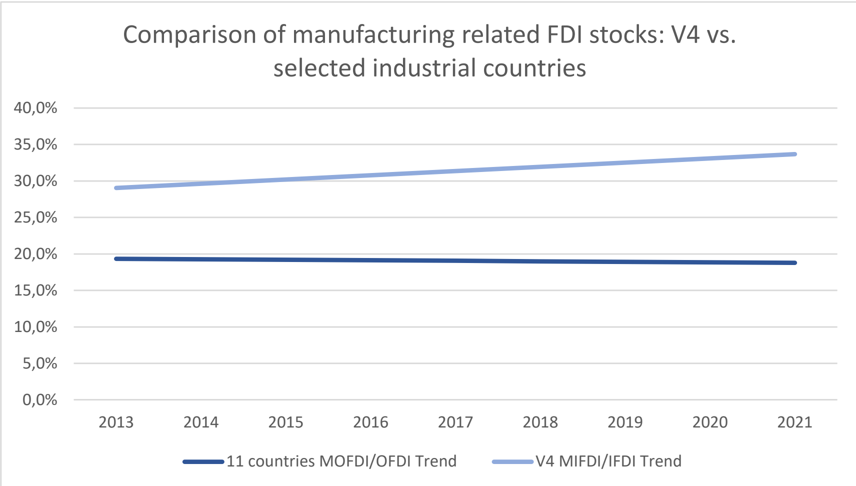
MIFDI stock/IFDI stock	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	32%	33%	33%	32%	29%	28%	28%	27%	26%
Hungary	21%	25%	11%	30%	42%	41%	43%	44%	49%
Poland	30%	29%	33%	32%	33%	31%	33%	32%	33%
Slovakia	32%	33%	33%	32%	32%	25%	33%	32%	35%
V4 average	29,1%	29,8%	28,5%	31,3%	33,2%	31,5%	33,1%	32,5%	33,4%
V4 average (trend)	29%	30%	30%	31%	31%	32%	33%	33%	34%

9. Table: MIFDI/IFDI stock changes in V4

The ratio of the MIFDI stock/IFDI stock in the Visegrad Four countries between 2013 and 2021

Own calculation based on OECD statistics, OECD, 2023

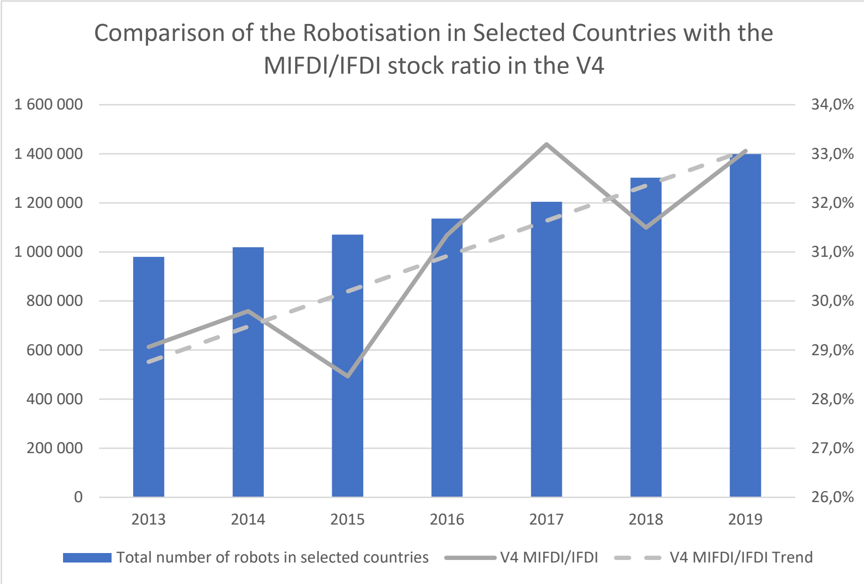
When investigating the relative positions of the manufacturing industry both in terms of the FDI "sending" (e.g., the eleven selected countries) and the "receiving" (e.g. the V4) countries, the outcome is that the V4 countries outperform their inward FDI related possibilities in manufacturing (16. Figure).



16. Figure: MOFDI/OFDI and MIFDI/IFDI trends

Comparison of the FDI stock ratios (MOFDI/OFDI and MIFDI/IFDI) of the V4 with selected leading industrial countries during the period 2013 – 2021 (Own creation on the basis of OECD statistics, OECD, 2023)

The results above indicate that the growth in robotisation in the leading robotised countries do not impact the investments in the manufacturing industry of the V4 countries negatively or if such negative forces exist, they are exceeded by other effects that appear to be more powerful. This finding is reinforced in the chart below (17. Figure); the increase of robotisation in the selected leading industrial developed countries is concurrent with the relative growth of the investments in manufacturing industries of the Visegrad Four countries.



17. Figure: Robotisation in selected countries vs. V4 MIFDI/IFDI

Comparison of the robotisation stock in the selected eleven leading industrial developed countries with the MIFDI/IFDI stock ratio in the V4 during the observed period (2013 – 2019)

Own creation based on OECD statistics, OECD, 2023

I performed qualitative research to augment the above-mentioned quantitative ones. As mentioned in the methodology section, I conducted interviews with both experts and company managers in the area.

First of all, several top managers of Hungarian subsidiaries of large multinational companies stated that they were not aware of backshoring activities either from their company or from the Hungarian manufacturing industry in general. According to them, it was also unlikely that backshoring would take place in the near future. Manufacturing experts from the V4 region shared the opinion of managers. The interviewees (university teachers, a researcher, a government official, and other experts) did not observe backshoring. They also did not believe that such activities would happen in the future. It was acknowledged that automation lowers the cost of production in the leading industrial economies, but despite that, the V4 region was still competitive as an investment destination.

The summary of the key benefits of the V4 region blocking backshoring mentioned by the experts:

- Competitive labour force: For example, the wage of a Hungarian manual worker is approximately one-quarter of a German one. This cost advantage matters despite the decreasing production costs in multinationals' home economies due to robotisation.

- Financial benefits: The governments and the investment promotion agencies support the investments of multinational companies with financial incentives.
- Low transportation cost: The region offers low transportation costs due to its short distance to West-European end-users and other European factories. This is essential, for example, for the battery industry.
- Reliable workforce: the production efficiency of the V4 exceeds many other regions from other continents.

The experts mentioned that a more common related symptom was that with the help of robotisation, more production activities of new products could stay in the leading industrial countries, as large multinationals could afford to produce more in their higher-wage home economies than a few years ago.

The third step of my data triangulation methodology was to cross-check the quantitative and qualitative findings with the literature. A related study also revealed that backshoring from the V4 was relatively few, and these tendencies were balanced by nearshoring activities to the region (Éltető, 2019). One reason for this "balancing mechanism" can be that the emerging economies also face robotisation ((Butollo, 2021).

As mentioned earlier, the V4 countries are still favourable investment destinations, and the region outperforms the world average in terms of incoming FDI (Kalotay et al., 2021). As already described in the literature review, some authors (Kinkel et al., 2015) found that robotisation indeed can decrease the willingness of Western European firms to implement offshoring. However, the results indicate that this observation is relevant only for investments outside of the European Union. This exploration is also grounded in the FDI-related gravity model, which shows that nearshoring is more advantageous than farshoring (Paniagua, 2015). Consequently, my reasoning is that the V4 region is especially attractive for West-European companies as an investment destination due to their EU membership and geographic proximity to the headquarters of the major European manufacturing companies. Therefore, the close location is an extra motivation for these companies to invest in the V4 region. This pro-investment motivation, together with other factors, seems to be significantly stronger for these companies than the probable negative effect on production-offshoring decisions due to the increase in production efficiency in the home factories thanks to the higher robotisation rate.

3.2. Technological Upgrading

As previously explained, the technological upgrading-related hypothesis is that global technological advancement supports technological upgrades in the V4 countries, mainly through the subsidiaries of large multinational companies.

There are several methods to measure technological upgrading in an economy: research and development-related investments, the number of patents registered, the number of STEM teachers, etc. Nevertheless, as I focus on robotisation in the manufacturing industry, the above-mentioned indicators are too generic for my study. Therefore, in quantitative terms, I rely only on robotisation. I augment the statistical findings with the results of my qualitative research.

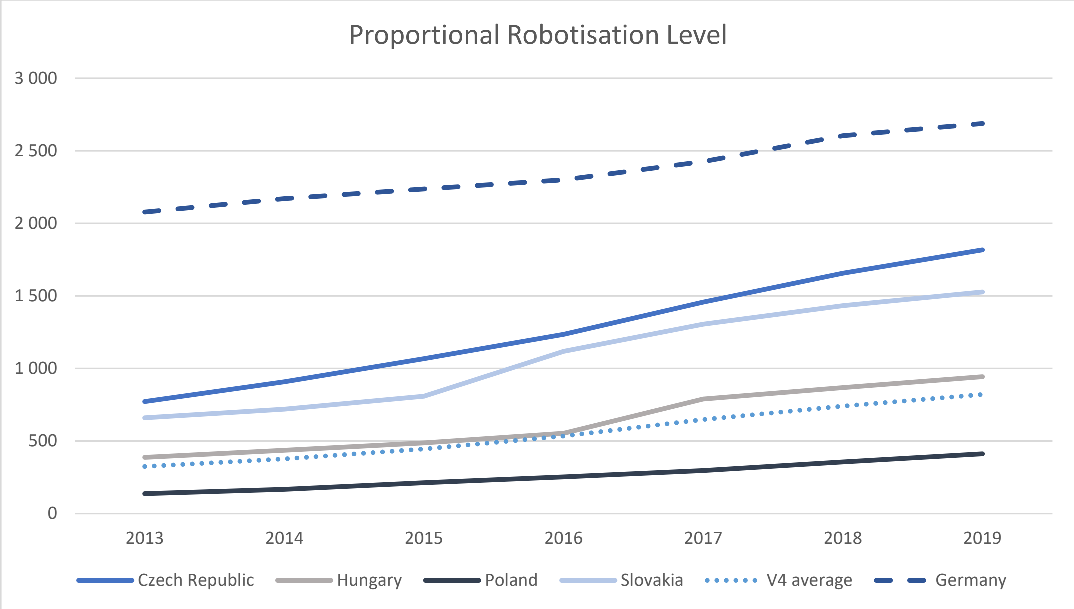
As revealed in the conceptualisation section, there is a global technological development, and the V4 countries are also expected to benefit from this process. Industrial robots are an important manifestation of technological development, especially for manufacturing industry-focused countries, as the higher the robotisation rate in a country, the more advanced the production technology used.

As the previous section indicates[41], there is an exponential growth of industrial robots worldwide. The question arises: to what extent the V4 countries are beneficiaries of this process?

When comparing the absolute values of the V4 countries with Germany (IFR, 2023a), the leading European robotised country, the difference is substantial: the German robot stock is more than four times larger than the V4 altogether[42]. However, the relative robotisation ratio is a more adequate indicator, as it can better predict upgrading tendencies. As displayed in the chart below (18. Figure, 10. Table), the robotisation rate increases in the V4, and the level of growth is steady in the Czech Republic and Slovakia.

[41] 3.1.1.

[42] The detailed robotisation numbers are in the Appendix.



18. Figure: Relative robotisation in Germany and V4

Changes in the robotisation stock per million inhabitants in Germany and the V4 from 2013 to 2019

Own creation on the basis of IFR, 2023a

Increase in Robotisation	2013 - 2019
Czech Republic	136%
Hungary	144%
Poland	201%
Slovakia	131%
V4 average	154%
Germany	29%

10. Table: Robotisation in Germany and the V4

Comparison of the German growth rate in robotisation with the V4 countries. Years compared: 2013 vs 2019.

Own creation on the basis of IFR, 2023a

According to the managers of subsidiaries of large multinational companies, there is a significant difference in the robotisation of the Hungarian subsidiaries and the German[43] factories. In the case of an OEM, the level of robotisation within the holding group is 70-80% in Western European factories and approximately 30% in the Hungarian factory. Other managers confirmed this ratio as well. The reason is that the cost of the workforce is much lower in Hungary. This cost-effectiveness of labour is still a crucial factor despite the growing robotisation.

[43] The companies interviewed were dominantly German.

However, there are different examples as well. In the case of a TIER-1 supplier of a car assembly factory, the level of robotisation was nearly the same in Hungary and Germany. As they mentioned, the German factory is a bit advanced in certain aspects, but they are not crucial. The reasoning is that the same products are produced in the same factories for the same customers and, as the requirements are mostly the same, the production line was also designed in a similar manner.

There is also an example of a situation when the Hungarian factory outruns the German one in the production design. In a TIER-1 factory in Budapest, the local management designed a new production line using cheaper, lighter robots. These new-generation robots cost much less than earlier, more robust robots. The investment became a success, and the management from the German factory came to scrutinise the Hungarian solution as the German production line was not effective enough anymore due to the use of too expensive, larger, earlier-generation robots. Also, there are several examples in the news on either starting a technology upgrading activity or reaching an important related milestone (Autopro, 2022, Autopro 2023).

In terms of regional outlook, the experts told me multinational companies dominated the automotive sector; therefore, the technology advancement level and the design and development process in the V4 region were similar in this domain. However, as some experts and managers mentioned, the Czech Republic was more advanced in technology adaptation, and the higher robotisation rate mentioned earlier also justifies this statement. There is a concentration of robots in these countries; robotisation is mainly taking place in the subsidiaries of large multinational companies.

Concerning the drivers for the robotisation in the V4, the finding in the literature that robotisation is higher where the salaries are higher (Céfalvay, 2019) was partially underlined both by some related statistics and by some opinions of managers. As robotisation is an investment, it is more profitable when the return is higher, e.g. the factor (labour) to be substituted is more expensive. However, it is essential to note that this general finding is valid only with limitations. For example, the robotisation rate in the Czech Republic (per capita numbers) outpaces several leading industrial European countries and shows a catching-up trend to the German numbers (IFR, 2023a). This trend is taking place despite the substantial wage differences (Eurostat, 2023). The main motives for robotisation are:

- increasing cost-efficiency: aligned with the above-mentioned substitution theory,
- supporting workers: in performing heavy, tiring, and non-ergonomic physical work,
- increasing production quality: decreasing the chances for human-related errors,
- solving the worker scarcity issue: maintaining 24-hour operations despite the lack of skilled labour.

The next logical question is whether robotisation is auspicious for the V4 economies. The interviewed managers and experts agreed that robotisation was advantageous for their companies and the V4 in general. It benefits companies by enabling a secure, time-efficient, and cost-effective manufacturing process. It is also helpful for workers by supporting them in accomplishing repetitive tasks such as lifting and processing heavy, non-ergonomic items. However, it should be noted that the managers also claimed that there is a workforce issue. In order to remain competitive, robotisation alone is not enough; workers possessing the necessary skills to cope with the new environment must also be available.

3.3. Upgrading in Global Value Chains

3.3.1. Global upgrading trends in GVCs

After investigating the potential impact of robotisation on technological upgrading, the next logical question is whether there is an impact on the upgrading in global value chains as well. Accordingly, I try to answer the related hypothesis: that the technological development in the subsidiaries of the large multinational companies in the V4 promotes upgrading these units in the global value chains.

A substantial part of global trade occurs within global value chains (Xing et al., 2021), and also GVCs are closely linked to FDI, as the latter was the primary driver of GVC expansion. (Qiang et al., 2021). A relevant question when analysing the tendencies within GVCs is to what extent there is upgrading at the level of the participating entities. Generally, upgrading is the "process of climbing up in the value chain in terms of value-added and skills" (Crescenzi et al., 2022). Upgrading can be considered at the level of individual companies, regions and countries (Crescenzi et al., 2022). In this section, I analyse it at the level of countries to identify global tendencies.

After an era of GVC participation-related growth, there has been a discontinuity in the former trend recently. As a European Central Bank paper states, "after more than 20 years of continued growth, the pace of GVC integration has slowed globally" (Cigna et al., 2022). This statement is underlined by the Global Value Chain Development Report (Xing et al., 2021). After reaching a peak before the 2008/2009 financial crises, the GVC participation rate[44] is stagnating[45] in trade- and production-based participation (11. Table).

Participation rate in GVCs %	1995	2008	2020
Trade-based participation	35,2%	46,1%	44,4%
Production-based participation	9,6%	14,2%	12,1%

11. Table: Global GVC participation rates changes

One of the measures for upgrading is to consider the domestic added value in exports (Taglioni et al. 2016). This measure is closely linked to the Trade in Value Added (TiVA) indicator. When measuring the TiVA in GVCs, the Foreign Value Added (FVA) content of exports is one of the most used indicators. It means the "value added of inputs that were imported in order to produce intermediate or final goods/services to be exported" (WTO, 2023 a). This FVA content of the exports/GDP ratio is connected to *backward* GVC participation, indicating the *buyer's* perspective on GVCs (WTO, 2023 a). The World Trade Organisation (WTO) has statistical profiles on countries' TiVA values in GVCs (WTO, 2023 b). The following table shows the changes in the FVA values for the five main robotised countries on the basis of the WTO statistics from 2010 to 2018 (12. Table). As the table indicates, there was a decrease in the foreign content of exports in the case of three countries (China[46], South Korea, and the USA), and the German values stagnated, while in the case of Japan, there was a substantial increase. As a general rule, it can be observed that the FVA values and, hence, the backward GVC participation decreased in the case of most of the selected countries in the observed period.

[44] It is measured as the portion of goods and services crossing border more than once out of total exports.

[45] It is adequate to use the stagnating expression trend wise, despite the lower percentages in 2020 than in 2008 as there is a high level of volatility in the data (and a relatively larger drop in 2019 and 2020) as seen in the related chart of the study (Global Value Chain Participation Rates, World, 1995 – 2020, Xing et al., 2021)

[46] China was excluded from the earlier analysis on the impact of robotisation on foreign direct investments for two reasons: the lack of data for MOFDI values and the non-developed status. It is considered in the upgrading related analysis as there is data available in this case, and this part of the study focuses on comparisons of values and not on the impacts, so the development status is less relevant.

FVA in Exports %	2010	2018	difference
China	19,2%	17,2%	-2,0%
Germany	22,7%	22,9%	0,2%
Japan	13,3%	17,2%	3,9%
South Korea	36,8%	32,0%	-4,8%
USA	10,9%	9,5%	-1,4%

12. Table: FVA changes for main robotised countries

Foreign Value Added content changes (2018 vs 2010) in gross exports in percentages[47] for the five selected countries (Own creation on the bases of WTO, 2023b)

The second widely used indicator is the Domestic Value Added sent to third economies (DVA GVC[48]). This indicator presents the domestic value added in goods or services exported to a partner economy that re-exports them to a third economy as embodied in other products (WTO, 2023 a). The DVA GVC is connected to the forward participation in GVCs and considers the *seller's* perspective in GVCs (WTO, 2023 a). In this case, there was an increase in the case of four countries, except for Japan[49](13. Table).

DVA GVC in Exports %	2010	2018	difference
China	17,5%	19,3%	1,8%
Germany	21,4%	23,4%	2,0%
Japan	27,4%	25,5%	-1,9%
South Korea	18,0%	21,5%	3,5%
USA	22,8%	26,1%	3,3%

13. Table: DVA GVC Export changes of the five main robotised countries

Changes in Domestic Value Added content of the five selected countries sent to third economies from 2010 to 2018 (Own creation on the basis of WTO, 2023 b)

[47] Difference means growth since 2010 while average means the non-weighted averaging of the FVA values of the selected countries.

[48] own creation as abbreviation for simplifying the related descriptions.

[49] It has to be noted that the Japanese data was substantially different from most leading robotised countries both in case of FVA and GVA GVC indicators in 2010, so by 2018 a convergence can be seen.

The total GVC GVC-related exports[50] can be seen in the table below (14. Table). It shows that the GVC-related exports have grown slightly in the case of most of the selected countries during the observed period[51].

GVC Related Exports %	2010	2018	difference
China	37,2%	37,2%	0,0%
Germany	44,9%	47,2%	2,3%
Japan	40,9%	42,9%	2,0%
South Korea	55,1%	53,8%	-1,3%
USA	34,3%	36,2%	1,9%

14. Table: GVC export changes of the main robotised countries

Changes in the share of GVC-related exports of the five selected countries from 2010 to 2018

Own creation on the bases of WTO, 2023 b

In addition to the changes in the GVC-related exports, it was also pertinent to investigate how the domestic added value is being set during the examined period. According to the related table (15. Table), the domestic value increased in the case of most of the investigated countries.

[50] The DVA reimports table (due to small percentages not analysed in detail) and the Domestic Value Added sent to Consumer Economy, in other the non-GVC related tables are found in the Appendix.

[51] This discovery is not in conflict with the earlier finding according to the Global GVC Development Report that GVC participation numbers were stagnating between 2008 and 2020 as there was a significant decrease during the years of 2019 and 2020.

DVA Exports	2010	2018	difference
China	80,8%	82,8%	2,0%
Germany	77,3%	77,1%	-0,2%
Japan	86,7%	82,8%	-3,9%
South Korea	63,2%	68,0%	4,8%
USA	89,1%	90,5%	1,4%

15. Table: DVA export changes of the main robotised countries

Changes in the share of DVA-related exports of the five selected countries from 2010 to 2018.

Own creation on the bases of WTO, 2023 b

The analysis above demonstrated the TiVA-affiliated landscape in general for the five inspected countries; it was still appropriate to scrutinise the manufacturing-linked[52] domestic value-added (DVA) values[53]. What is noticeable (16. Table) is that differences between countries follow a similar pattern to the generic DVA values. However, there are two main differences. The first is that the manufacturing-related GVC participation is higher than the overall participation in GVCs, except in South Korea. Regarding the total domestic value added, the difference is the opposite; the values are slightly lower in the case of manufacturing than when the total export is considered.

2018	FVA	DVA GVC	GVC total	Direct VA	DVA total
China	19%	33%	**52%**	48%	**81%**
Germany	27%	23%	**51%**	49%	**73%**
Japan	21%	20%	**41%**	59%	**79%**
South Korea	35%	17%	**52%**	48%	**65%**
USA	16%	30%	**46%**	54%	**84%**

16. Table: Manufacturing-related TiVA values of the five selected countries in 2018

Own creation on the bases of WTO, 2023b

3.3.2. Upgrading in GVCs in the V4 region

To compare the upgrading trends in GVCs in the V4 region, I conducted TiVA-related calculations similar to the ones in the Global Analysis section[54]. The table below (17. Table) shows how much GVC-related exports have increased during the investigated

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[52] The term "manufactures" of WTO is not necessarily in complete overlap with the term "manufacturing" used by OECD (in case of the outward FDI to manufacturing).

[53] Manufacturing-related DVA values are only available for 2018, so a chronological comparison is not possible.

[54] Only the main results tables are presented here, the other V4 TiVA related tables can be found in the Appendix.

period (2010 – 2018). As it is exposed, the GVC participation was strengthened in each V4 country. The share of exports with forward or backward linkages to GVCs was above 60% in the case of three countries in 2018, while the Polish value was closer to 50%.

GVC Related Exports %	2010	2018	difference
Czech Republic	58,2%	62,2%	4,0%
Hungary	62,1%	63,4%	1,3%
Poland	50,6%	53,8%	3,2%
Slovak Republic	62,5%	67,2%	4,7%

17. Table: GVC exports in V4

Comparison of the share of GVC-related exports in the V4 in 2010 and 2018

Own creation on the bases of WTO, 2023b

The share of domestic value-added, e.g., the value that can represent upgrading quantitatively, decreased during the observed period in the Czech Republic, Poland, and the Slovak Republic, while it increased by 2 per cent in Hungary[55]. As a result, according to the Trade in Value Added indicators, no upgrading occurred in most of the V4 countries in the observed period (18. Table).

DVA Exports	2010	2018	difference
Czech Republic	60,0%	57,8%	-2,2%
Hungary	51,7%	53,7%	2,0%
Poland	70,3%	69,0%	-1,3%
Slovak Republic	55,5%	52,0%	-3,5%

18. Table: DVA exports in V4

Comparison of the share of Domestic Value Added in exports in the V4 in percentages in 2010 and 2018

Own creation on the bases of WTO, 2023 b

The manufacturing-related main TiVA indicators in the V4 show (19. Table) that the integration of the manufacturing industry to GVCs is higher than in the case of all the sectors within each V4 country. On the other hand, the domestic added value it creates is lower in each case than in the case of the aggregate values of the whole economy.

[55] The Hungarian increase in domestic value added content in export is cross-checked with the literature and an article confirms the progress trend-wise, calculated in a different timescale (2010 – 2016) from a different source (OECD), the Hungarian DVA values are: 51,15 % (2010) and 56% (2016) (Gerőcs, 2022).

2018	FVA	DVA GVC	GVC total	Direct VA	DVA total
Czech Republic	49%	16%	**65%**	35%	**51%**
Hungary	57%	11%	**68%**	32%	**43%**
Poland	40%	23%	**63%**	37%	**60%**
Slovak Republik	58%	13%	**71%**	29%	**42%**

19. Table: Manufacturing TIVA in V4

Manufacturing-related TiVA values of the V4 countries in percentages – compared to the total exports in 2018

Own creation on the bases of WTO, 2023b

The next and final related step of the analysis was the comparison of the manufacturing-related TiVA values of the selected five main robotised countries and the V4 countries (20. Table). What can be observed is that the manufacturing industries of the V4 countries are substantially more integrated into global value chains than the ones of the selected countries (China, Germany, Japan, South Korea and the USA). Also, the domestic value-added content in exports is significantly lower in the case of the V4 than in the group of selected countries. Poland is dissimilar to the other three V4 countries in two aspects. First, it is less integrated with GVCs, and second, its domestic value-added contribution to exports is higher; it is closer in terms of DVA share to South Korea than to Hungary or Slovakia.

Ranges (%)	GVC total	DVA total
Five countries	46 - 52	65-84
V4	63-71	42-60

20. Table: GVC participation and DVA values comparison

Comparison of the manufacturing-related TiVA values (% of total export) of the selected main robotised and the V4 countries (Own creation on the bases of WTO, 2023b)

As mentioned by the respondents of my field research, the upgrading-related situation was similar in the V4 countries. However, they also informed me of some differences, and it is worthwhile to revisit some of them briefly as they can also justify the diversity in some results in the quantitative analysis section.

Poland is larger than the other three countries; its population (38 million inhabitants) is more than the combined population of the Czech Republic, Hungary, and Slovakia. Consequently, the local market is the largest in the region and creates a larger buying force, so the domestic company structure is more substantial than in the other V4 countries.

In the Czech Republic, Skoda makes a difference as the only automotive OEM with a headquarter[56]s in Central Europe. The company has relatively high autonomy within the VW group, has its own R&D programme, and cooperates with local universities.

Hungary has five automotive OEMs present, and also the building of significant battery production capability is in progress. Besides, the country has companies with extensive research and development activities like: Bosch, Continental, Knorr Bremse, and thyssenkrupp[57].

Slovakia is the smallest country, and it impacts its position in GVCs. According to a local expert, the main problems are dependency on the automotive industry and the lack of domestic suppliers embedded in global value chains.

Notwithstanding, despite some differences in their economies, the GVC-related positions and tendencies are alike in the V4. Hence, they are analysed as one block in terms of GVC-related upgrading.

The literature confirms the significant difference between the leading industrial countries and the V4 in upgrading. A recent book on the upgrading possibilities of Hungarian subsidiaries of multinationals (Szalavetz, 2019) builds on interviews with top managers, similar to my field research. However, the discussions took place earlier (approximately ten years ago), so it is interesting to compare the results. As the book mentions, within the subsidiaries of multinationals, a *natural way of upgrading* can be recognised: e.g. a subsidiary starts with a relatively simpler function and then develops gradually as more knowledge-intensive functions are received from the daughter companies (Szalavetz, 2019). A far-reaching finding explored that the gap between multinational headquarters and the subsidiaries will last long due to the distinct types of upgrading processes. While lead companies can focus on core higher-added value activities through digitalisation, what remains for subsidiaries is the functional and process upgrading by the narrower Industry 4.0 developments (Szalavetz, 2019). My findings are harmonious with the ones in the book; the novelty is that in some niche fields, the position of the Hungarian

[56] Skoda is member of the Volkswagen Group, but as a separate company.

[57] The company name ‘thyssenkrupp’ is written with a small ‘t’.

subsidiary can even outpace the German headquarters in the Baldwin (Baldwin, 2013) smile-curve relevant roles.

According to the outcome of my field research, there is a development gap between the V4 region and the developed Western European countries. As a university teacher mentioned: “The gap between Germany and the V4 will always be there..” This gap is also present in terms of the position within the GVCs. In accordance with my field research, the most prominent developments and innovations took place within the manufacturing processes: how to improve the manufacturing process, the production line, tools, and machines used for production. This is done to make production quicker and more efficient and increase product quality. Although these countries have succeeded in upgrading production-related processes, some experts assumed this focus resulted in a relatively low number of high-value-added activities. This resonates with the literature in the field due to the uneven distribution of tasks in GVCs: “The V-4 are considerably in charge of the assembly activities within the GVCs, which is reflected, among other things, in the low domestic value shares in exports and production compared to the EU or OECD averages” (Cerná et al., 2022)

Despite the negative consequences mentioned, most of the respondents claimed that there was upgrading in progress. Even if it is primarily a result of development in the field of relatively lower-value-added, production-focused activities, this is still a shift from the former position. Thereupon, these developments can be considered upgrading in qualitative terms. As the literature confirms, this upgrading process results from the general technology development wave, within which robotisation has an outstanding role in the manufacturing industry.

With regards to the natural, gradual upgrading process, the managers told me that the decision on which subsidiary focused on what kind of activities depended on the local competencies. One specific innovation process starts only in one factory. Once it is proven to be successful at one location, then the new methodology, solution, and tool are usually transferred to other plants as well. Another respondent highlighted the role of time in the upgrading process. A team of a new subsidiary is tasked with relatively simpler tasks at the beginning, and once these new processes are maintained successfully, more involved tasks are allocated to them. Accordingly, the subsidiaries must undergo a “proving cycle” when climbing the smile curve.

There were examples of surpassing headquarters both in volume and quality. An illustration of the first one is a German-owned automotive company; the production level of certain products in the Hungarian factory has reached 70-80% of the total production volume. Another case supports the higher upgrading position in qualitative terms. In the case of another German multinational company, the research and development centre in Hungary is the largest globally in terms of headcount, and there are specific fields where the global R&D team is being coordinated from Hungary.

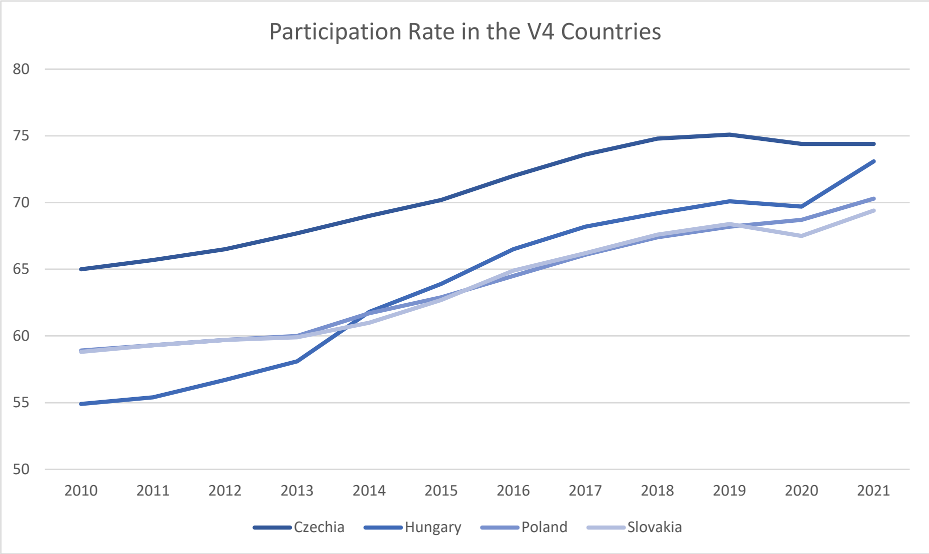
3.4.Jobs

The field which gets the most attention in terms of robotisation is the job market. There are numerous articles and studies debating the potential disappearance of working positions due to automation. To validate the related hypothesis, e.g. that the increase in the level of robotisation in the manufacturing sites of multinational companies in the V4 region has an impact on the number and type of workers employed, in this section, I provide an overview of the current situation in the V4 region, relying on the outcomes of both quantitative and qualitative research activities.

3.4.1. Analysis of related statistics in the V4

I start the quantitative analysis with some macro-level statistics as they can provide adequate background information for the evaluation of the job market in the region.

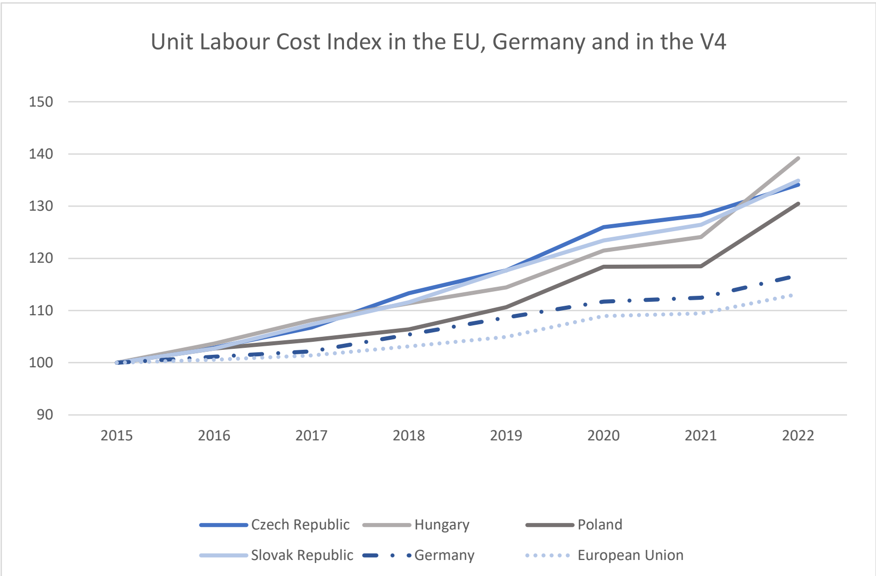
When I investigated the labour-related data in the Visegrad region, one aspect to examine was the participation rate, e.g. which percentage of the population aged 15 – 64 worked (OECD, 2022). As the chart below explains (19. Figure), the participation rate in the V4 countries continuously grew during the examined period (HSCO, 2023.) The trend in the V4 is aligned with the general EU trend, where the participation rate increased from 61,2% (2002) to 68,4% (2023) (HSCO, 2023).



19. Figure: Participation rate in the V4 countries during 2010 – 2021[58]

Own creation on the basis of HSCO, 2023

The other related aspect is the trends in labour costs. Labour costs have risen intensely during the last seven years (20. Figure). The corresponding growth rate is significantly higher in the V4 countries than in the European Union or Germany.



20. Figure: Unit labour cost in EU, Germany and V4

The unit labour cost index is calculated based on the hours worked in the EU 27, Germany, and the V4 countries. 2015 equals 100%. (Own calculation on the basis of Eurostat 2023[59])

[58] The table with the numerical values is in the Appendix.

[59] The related Table is found in the Appendix.

From a production efficiency point of view, the increase in labour costs is a negative development. However, this effect is balanced by the fact that, as the statistics show, there is a growing need for the workforce in these countries.

For the micro-level quantitative study, I chose two multinational companies with production subsidiaries in Hungary. One manufacturer of complex and high-value automotive products, while the other produces and packages simple healthcare products. This selection aimed to represent the different technology levels in the Hungarian manufacturing industry.

The first company to investigate was the Mercedes-Benz Group (Mercedes Group[60]). Mercedes is one of the leading European car manufacturers, possessing an approximate 5% market share of the European market (Statista, 2021). Its primary activity is the production of passenger cars. The Hungarian plant was opened in 2012 in Kecskemét and is one of Hungary's few automotive OEM factories where complete car assembly occurs.

Financial information from the group level from 2016 to 2020 was analysed, and regarding the Kecskemét Factory, the time interval 2017-2021 was considered[61]. In both cases, the sources of the information were the annual reports of the companies (Mercedes, 2023[62])

Regarding the other KPI, the number of manual and non-manual workers[63], data was available for both the group (21. Table) and the local subsidiary[64] (22. Table).

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[60] To shorten the name of the company, in the analysis the name „Mercedes Group" is used.

[61] The reason for the differences is the difference in data availability in group and local level during the time of the related analysis.

[62] The several reports are refenced under one aggregate reference: Mercedes, 2023, referring to the time of download and not the time of preparation.

[63] Trainees and interns are excluded from the group numbers. Also, the terminology is different: whereas in of the Hungarian factory, "manual" and "non-manual" is translated from Hungarian, in case of the Group report the phrase industrial is taken, but the term "administrative" is transferred to "non-industrial" to better match the terminology of the local factory. The terms used at group and local level might not fully cover each other, but as the tendencies are considered within each category (within the group and within the local factory), the comparison can still provide a relevant finding.

[64] Mercedes-Benz Hungária Kft. serving as the Hungarian headquarter for sales activity was not considered in the analysis, as the company has less than hundred employees, it is not significant from the analysis point of view (MBH, 2023).

Mercedes Group	2 016	2 017	2 018	2 019	2 020
Industrial Workers Trend	143 957	145 794	147 631	149 467	151 304
Non-industrial workers Trend	125 690	126 858	128 027	129 195	130 364

21. Table: Group: manual vs. non-manual workers

Comparison of the number of manual and non-manual workers at the Mercedes Group (trend data[65])

Kecskemét Factory	2017	2018	2019	2020	2021
Manual workers	3 052	3 152	3 252	3 352	3 452
Non-manual workers	838	928	1 018	1 109	1 199

22. Table: Kecskemét: Group: manual vs. non-manual workers

Comparison of the number of manual and non-manual workers at the Kecskemét Factory (trend data)

What was more appropriate to investigate than the absolute values: the ratio between the manual and non-manual workers (23. Table). The following observations were made. First, the difference is extensive, and it is mainly because, in Kecskemét, the activities are centred around manufacturing. In contrast, at the group level, several other activities (research, logistics, marketing, etc.) are maintained. The second is that the ratio of non-manual workers is increasing in Kecskemét as well, and it can indirectly mean that there is some upgrading within the production-related activities. There is a relatively more significant need for employees not being directly engaged in the production process. A recent development might accelerate this process. As already mentioned in the literature review, Mercedes started to employ new humanoid robots (Apptronik, 2024). The trials are starting in the Hungarian factory, in Kecskemét (Financial Times, 2024). According to the article the reason for choosing Hungary was: "a country facing a labour shortage for auto jobs, and where the unions are less vociferous than in Germany" (Financial Times, 2024).

Ratio of non-industrial/industrial workers	2 016	2 017	2 018	2 019	2 020	2021
Mercedes Group	87%	87%	87%	86%	86%	
Kecskemét Factory		27%	29%	31%	33%	35%

23. Table: Comparison of employee categories

Comparison of the ratio of non-industrial and industrial workers at the Mercedes Group and in the Kecskemét Factory

[65] Created with the Trend function of Excel to eliminate yearly volatility

The healthcare company is Procter & Gamble. Procter & Gamble is a nearly two hundred years old company headquartered in Cincinnati, Ohio. The company is the largest consumer goods company in the world (Statista, 2023). The company has two factories in Hungary: one in Gyöngyös and another one in Csömör. The two factories are owned by one company called Hyginett Kft.

In the absence of employee-structure-related data at the global level, only the Hungarian subsidiary was analysed. Even though the number of employees has doubled in the last ten years, the share of manual and non-manual workers remained the same (24. Table). It shows no actual development in the process; the factories dominantly focused on simple assembly-oriented duties.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
manual workers	77%	76%	74%	76%	76%	76%	76%	76%	76%	76%
non manual workers	23%	24%	26%	24%	24%	24%	24%	24%	24%	24%

24. Table: Comparison of employee categories

Comparison of the ratio of non-industrial and industrial workers at P&G Hungary[66]

When measuring the upgrading tendencies within the companies, the ratio of the non-manual and manual workers was used. In the case of Mercedes, there is an increase in the share of non-manual workers in Kecskemét, although the ratio is considerably lower than at the group level. In the Hungarian P&G factories, on the other hand, the balance is stable through the observed period.

3.4.2. Qualitative research on the job market in the V4

Regarding the motives for robotisation, the managers mentioned that the primary goal was always to increase cost-effectiveness, and the headcount decrease in specific production segments implies that goal. The general trend is a decrease in the directly production-related manual jobs and an increase in the non-manual ones. The motive behind the decline in unskilled work is the automation of simple, repetitive tasks. These tasks are easy to automate, are not ergonomic enough, and it is hard to find a reliable workforce with the required quantity, especially for 24-hour operations. The other side of the coin is that automation and robotisation change the operation of many companies; more focus is needed on planning and controlling activities, and the role of preventive maintenance is growing. To serve this rising level of activities, more indirect workers

[66] On the basis of Procter statistics (Procter, 2023).

who are not directly employed in the assembly and production lines are needed. These workers cover a wide range of professions: skilled maintenance workers, engineers and staff for administrative and support functions.

An automotive OEM factory manager explained the reasoning for the motivation mentioned above. It is the technical set-up of the company's business model which defines the production time for one car, and consequently, the latter defines the number of direct workers required to produce a vehicle. There is a continuous drive within automotive OEMs to make the production process more efficient. This motivation is caused by the ever-increasing costs, which can only partially be transferred to the customers. Examples of these kinds of costs are energy prices, raw materials, salaries, etc. To balance the difference between the increase of expenses and the lesser increase in income, cost-efficiency-related measures, e.g. automation, should be implemented. To highlight how profitable robotisation can be, in a Budapest-based factory, one robot can spare the cost of twelve workers when calculating the 24-hour operation time, the robot's investment cost and life span and the worker-related costs.

Besides, the motives and the impacts of robotisation on employment are also important. As mentioned by the interviewees, the number of directly production-oriented, manual jobs was decreasing, and on the other hand, the number of non-manual, indirectly production-oriented jobs was increasing. The latter tendency (partially supported by the micro-level quantitative analysis) also has a technology upgrading relevance: it helps form a larger group of skilled experts who can perform higher value-added tasks.

As a manager of a V4-located production factory of a multinational company said, "Nobody should fear automation". This statement is sustained by an article by economists working in the field in regard to the US labour market: "It should also be noted that even under the most aggressive scenario, we are talking about a relatively small fraction of employment in the US economy being affected by robots. There is nothing here to support the view that new technologies will make most jobs disappear and humans largely redundant (Restrepo et al., 2017)."

After comparing my findings with other scientific studies, it appears that the V4 case supports the "optimistic" view of automation researchers rather than the "pessimistic" one. The steady growth in the number of installed robots, along with the scarcity of production workers, does not support the notion that "robots are taking our jobs," as some have predicted (e.g. Ford, 2015). The results of my interviews align with the observations of Klenert and his co-authors, who found positive correlations between employment and robotisation in Europe (Klenert et al., 2023). However, one of their conclusions, that current robots are merely updates of earlier versions without significant changes to their impact capability, seems to be outdated[67]. As pointed out by one manager, the new, smaller robots are significantly lower-priced compared to earlier, larger, and more robust robots. The modern, lower-cost robots possess greater flexibility and cooperation functions that can alter the current situation in the future.

[67] Although the article was recently published, the analytical timeframe does not involve the latest developments.

4. DISCUSSION AND RESULTS

4.1. Analysing the Impact of Robotisation on Foreign Direct Investment

As explained in the conceptualisation section, the initial assumptions were the following:

- robotisation in the leading industrial countries negatively affects their foreign direct investment in the manufacturing sectors of less developed countries,
- the above-mentioned theory is valid for the V4 countries as well.

I started my investigation on the first assumption, e.g. if a general justification can be found on the geographical impacts of robotisation on the volume of investments. The first finding was that the outward FDI stock to manufacturing is growing slower than the total outward FDI stock in the selected leading industrial countries. This finding strengthened the initial supposition, and therefore, further calculations were made in the field of manufacturing-related FDI. However, by building on the findings of the literature and my quantitative and qualitative analysis, I cannot find an unambiguous general negative link between robotisation in the leading industrial countries and the investments from these countries to the manufacturing sector of less developed[68] countries.

The question arises as to why the related prophecies (e.g. Lund et al., 2019) are not yet materialising.

Part of the answer was given by one of the senior managers of a car manufacturer: he emphasised the complexity of the decision-making process for investment. For every investment-related decision,[69] there is a checklist to go over in the headquarters, and this list includes approximately sixty-eight factors. These factors include the market environment, the existence/non-existence of customs, the availability of an educated workforce, the supply chain situation, the role of trade unions, logistical, political, and demographic aspects, etc. As a result, the level of automation/robotisation in the

[68] The „less developed" does not mean developing, it contains all the countries which are not leading industrial countries (e.g. Germany, Japan, the USA, etc.) including developed ones (e.g. the V4).

[69] It also includes the decision whether to sustain an earlier investment.

headquarters factory and the derived implications alone are not the decisive factors in the future of a subsidiary.

Also, the statistics show an increase in inward foreign direct investment in manufacturing in the Visegrad Four. This growth was visible both in absolute and relative values. The absolute growth means that MIFDI[70] stock increased throughout the examined period. The relative growth is derived from the ratio of MIFDI stock versus IFDI[71] stock within the particular V4 countries. In a simplified formula:

$$\Delta \mathbf{MIFDI\ stock}^{\mathbf{V4}} / \Delta \mathbf{IFDI\ stock}^{\mathbf{V4}} > 1$$

2. Equation: MIFDI/IFDI-related changes in the V4

Where,

ΔMIFDI: is the annual growth rate of the inward foreign direct investment stock in manufacturing in the V4 countries in the observed period,

ΔIFDI is the annual growth rate of the total inward foreign direct investment stock in the V4 countries in the observed period.

Besides the investment volume, I also analysed the potential that a subsidiary factory was closed due to increased robotisation in large multinational companies' headquarters' factory. Consequently, I tried to answer whether backshoring from the manufacturing industry in the V4 has taken place during the last decade. As it was found both based on the literature and the field research, there is no evidence for significant backshoring.

Following the literature on push and pull factors for an investment decision (Dunning, 2004; Szunomár, 2020), I explore how these factors justify the lack of backshoring from the V4.

On the one hand, there are some adverse developments on the "push" side for investments, as robotisation in the headquarters of large multinationals probably has a decreasing "force" on efficiency-seeking investments, which is often the case in the manufacturing sector of the V4. Besides, as explored in the empirical analysis section,

[70] As introduced earlier, MIFDI stands for inward foreign direct investment in manufacturing.

[71] IFDI means inward foreign direct investment.

production costs have increased in the V4, which is a decrease in the "pull" forces for investments.

However, on the other hand, the production is still much more cost-efficient in the V4; according to a manager, Hungary, for example, is still considered a "low-cost country" and has substantial benefits when considering an investment decision. This means that although efficiency-seeking is still a critical factor in investment motivations, the relative decrease in related efficiency does not cause inefficiency in absolute terms. Additionally, as mentioned earlier, the factor mix for an investment decision is quite complex; it cannot be narrowed down to the cost of robotisation in the headquarters versus the cost of the workforce at the subsidiary.

The finding about the nexus of developed leading countries and the V4 during the last decade can be summarised in the formula below:

$$\mathbf{\Delta PushHQ^{R} + \Delta Pull\ Sub^{L+Lc} \ll PushHQ^{Fo} + Pull\ Sub^{Fo}}$$

3. Equation: The relation of push and pull factors in the V4 in the context of the study

Where:

$\Delta PushHQ^{R}$ is the new, changed value (usually a decreased one) in the push factors at the headquarters due to the changes in the robotisation rate (usually an increase creating a decrease in production costs) in the headquarter factories, and

$\Delta Pull\ Sub^{L+Lc}$ is the new, changed value in the pull factors (usually a decreased one) in the local subsidiary due to the changes in the availability (usually a decrease) and cost of labour (usually an increase creating an increase in production costs).

Fo[72] means other investment-related decision-making factors both in the headquarters economy (in our case[73], usually in Germany), ranging from the overall market forces on the company (e.g. a drive to lower production costs) to the high salary cost of employees in the headquarters factories and also in the countries where the subsidiary is located (in our case in the V4), measuring the utilisation opportunities for already established facilities and the good logistics possibilities, etc.

[72] Simplifying the problem, the other factors are presented as static ones, as the focus of this paper is the changes of two factors: robotisation and labour related ones.

[73] According to the interviewed organisations.

The formula shows that the sum of the decreased values of both the robotisation-related push factor and the labour availability and labour cost-related pull factors are still substantially smaller than the aggregated value[74] of all the other push and pull factors. In other words, robotisation and the changes in the local labour market probably had a negative impact on the attractiveness of the V4 manufacturing sector. However, due to the stability or even increase of other factors, the manufacturing industries of the V4 region are still attractive destinations for investments.

When investigating what the other factors are that make the V4 still an attractive destination for investors, the answer to the question is probably the gravity model.

As shown in the literature review (Paniagua, 2015 and Dorakh, A., 2020), there is a negative correlation between FDI flow and distance. It was also found that the new member states received significantly more FDI due to their EU membership than they would have received as non-EU members (Dorakh, A., 2020).

Following the push and pull factors-related (Dunning, 2004 and Szunomár, 2020) expression form applied in Finding 4:

$$\textbf{Push EUDev}^{\textbf{EU}} + \textbf{Pull V4}^{\textbf{EU}} > \textbf{0}$$

4. Equation: The effect of EU membership on push/pull

Where,

Push EUDev^{EU}: The push factor of the developed EU member countries to invest within the EU.

Pull V4^{EU}: The pull factor of the V4 countries to attract investors from the developed EU members.

Therefore, the assumption is that one of the reasons[75] why the Visegrad Four countries could invert the manufacturing-related FDI trends is their EU membership and the closeness to the leading European industrial FDI-source countries.

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[74] In order to focus on the key factors of this study, the analysis was carried out in a "ceteris paribus" manner, e.g. the other investment related factors were considered as static ones.

[75] There are obviously other reasons behind the important role of the manufacturing sector, one key one is the government intentions and support for manufacturing-related investments in several V4 countries.

The analysis did not support the original assumption, as it was not proven that the Visegrad Four region is losing investments as a result of robotisation. On the contrary, it seems that the V4 countries are still relative winners of the global investment process. Therefore, **I *reject* the related hypothesis as no evidence has been found that the robotisation-related growth in the leading industrial countries has a negative impact on the foreign direct investments of the leading multinational companies in the manufacturing sector of the V4 countries.**

4.2. Investigating the Technological Upgrading Progress

My technological upgrading-related assumption was that global technological development enables technological upgrading in the V4 countries. I also presumed that this process occurs mainly via large multinational companies.

As described in the Empirical Analysis chapter, the robotisation-related growth rate in the V4 outpaces many leading industrial countries, including Germany. As robotisation itself is considered an important factor signalling technological upgrading, I understand there is a "catching-up" process in the V4 to the leading industrial countries in this respect.

The qualitative research supports this claim; both the managers and the experts in the field confirmed that they had noticed a technological upgrading process. As mentioned earlier, there are examples of the level of automation in the V4 subsidiaries being very close to the equivalent manufacturing sites in the leading industrial countries. In a certain case, the Hungarian factory oversteps the German factory in the quality and performance of the robots deployed. In addition, in recent years, significant developments have taken place in research and development activities, as some multinational firms opened up new research centres or expanded their existing ones in the V4.

This development process can be expressed in a simple formula:

$$\Delta \mathrm{Up}^{TECH} > 0$$

5. Equation: Technological upgrading

Where,

$\Delta \mathrm{Up}^{TECH}$ means technological upgrading.

However, the upgrading process is far from complete. As was mentioned in the analysis, in the case of a Hungarian subsidiary of an automotive OEM, the robotisation rate of the production activities is only approximately 30% compared to the 70-80% of the Western European counterparts. It is still an open question whether this gap will ever be entirely closed or how long the upgrading process will take. According to the related literature, as robotisation is an investment to decrease the cost of employment, it is more cost-effective to implement it in cases where the salaries are higher (Cséfalvay, 2019). Although the labour costs have increased in the V4, the employment costs are still significantly lower than in Western Europe, for example. Therefore, from an investment perspective, it is questionable whether an absolute level off in production automation is ever reachable for the V4 manufacturing industry.

Whether a technology upgrading-related "glass ceiling" exists in the manufacturing sector of the V4 or not, as the statistics and the primary research results show, there is currently an upgrading process in the region. On the basis of my analysis, **I *accept* the second hypothesis. I found evidence that there is a technological upgrading process in the manufacturing sector of the Visegrad Group countries, mainly due to the presence of large multinational companies.**

4.3. Upgrading in Global Value Chains as a Result of Technological Development

The related assumption was that the V4 countries upgraded the GVCs due to the ongoing technological developments in the local factories of large multinational companies. The reasoning was that primarily multinational companies invested in robotisation, and also the higher level of automation enabled these units to gain control over more complex activities.

However, my quantitative analysis did not support this assumption. First of all, except for Poland, the V4 countries are substantially more integrated into GVCs than the five selected leading industrial countries. As the previous section indicates, technological upgrading takes place mainly through the multinational companies in the region; this fact might provide a ground for GVC-related upgrading as well. Nevertheless, according to the TiVA statistics, there is no upgrading in the GVCs in the V4 region during the period 2010 – 2018.

The manifestation of this relationship in a formula is the following:

$$\Delta \mathbf{Up}^{GVC} = \mathbf{0}$$

6. Equation: Upgrading of the V4 in Global Value Chains from 2010 - 2018

Where,

ΔUp^{GVC} means upgrading in GVCs.

Notably, the data availability is limited, and the change mentioned above in TiVA values, for example, shows the position of the entire economy and not only the manufacturing industry. However, the literature (e.g. Szalavetz, 2019) confirms the significant differences between the position of the V4 companies in GVCs and the headquarters companies of large multinationals.

Why is there a difference between the identified progress in technological upgrading and the non-existing GVC-related upgrading?

One possible answer is that many developments (e.g., the opening of research and shared service centres) occurred only recently, so they are not yet shown in TiVA values. Even if there is an assumption that the TiVA values might have grown in the last few years (since 2018) in certain V4 countries[76], the gap is still likely to be substantial compared to leading industrial countries.

The more likely answer is that there is a considerable difference between the various kinds of subsidiaries of multinational companies in the V4. As the two example companies in the micro-level quantitative analysis showed, the two factories in Hungary performed different upgrading-related values. One of them is a factory of an automotive OEM producing high-value products, while the other is a factory performing simple assembly and packaging of relatively low-value products. This means there is a duality within the subsidiaries of multinationals in the V4 manufacturing industries. This duality is different from the duality observed between multinationals and domestic companies (Éltető, 2021); in this sense, these economies have a "double duality". There are examples of companies with significant technology developments, e.g., increasing research and development activities, shared service centres, functional and process upgrading due to automation, robotisation and other Industry 4.0-related developments. On the other hand, many

[76] For example a 2% growth was already acknowledged for Hungary during the period 2010 to 2018.

multinationals still perform relatively low-value-added activities in the V4. Examples of them are, for example, the recent implementations of battery factories in Hungary, which mean substantial investments in volume, but the forecasted value-added is low (Győrffy, D., 2023). The value-added statistics show that the latter outperforms the first category.

When considering the related hypothesis, e.g., the technological development in the subsidiaries of the large multinational companies in the V4 promotes the upgrading of these units in the global value chains, two different observations conflict. On the one hand, it became apparent from the interviews with managers that in some "best practice" examples, the increase in knowledge-intensive activities certainly supports upgrading the concerning unit in its value chain. On the other hand, as the statistics and the literature confirm, these promising examples were not yet strong enough to change the entire situation, e.g. that the manufacturing industry of the V4 still dominantly focuses on assembly activities, which are relatively low-positioned in Baldwin's "smile curve" (Baldwin, 2013).

In addition to the above-mentioned reasoning, it is essential to note that the V4 countries are "shooting on a moving target", e.g. there is a global technological process benefiting everyone, including the headquarters of large multinational companies. Although the V4 countries show compelling statistics regarding the increase in robotisation, the catching-up can be less noticeable in other more qualitative developments (for example, the use of artificial intelligence in product design processes).

Consequently, although there is an assumption that the progress in technological upgrading is a "positive force" in GVC-upgrading as well, as no evidence was found to prove it on a general level, **I *reject* the third hypothesis, that the technological development in the subsidiaries of the large multinational companies in the V4, promote the upgrading of these units in the global value chains.**

4.4. Analysis of the Effects of Robotisation on Employment

As introduced earlier, the employment-related hypothesis is that the increase in the level of robotisation in the manufacturing sites of multinational companies in the V4 region impacts the number and type of workers employed. In the conceptualisation section, I had several assumptions supporting this hypothesis. One of them is related to the robotisation in the headquarters. For example, if the production costs in Western European factories can be increased substantially due to robotisation, then the willingness for efficiency-seeking MOFDI[77] might decrease in these companies. Notwithstanding, this assumption can be ruled out as Hypothesis 1 was already rejected. As there is no evidence of the decrease in manufacturing-related investments in the V4 due to robotisation in the leading industrial countries, this implies that a negative impact on employment in the region is also not provable.

The second assumption, e.g. that the increasing robotisation in the V4 subsidiaries of large multinationals negatively affects the number of employees in these factories requires a more thorough investigation.

As described in the literature and mentioned by the managers, the key motivation in manufacturing is keeping production costs low. With the rise of automation and technology development, the earlier capital versus labour nexus is extended with technology improvement. This change can also be expressed formally following the production function-related studies introduced in the literature review. The initial production function is as follows (Mankiw, 2009):

$$\mathbf{Y=F(K,L)}$$

7. Equation: The production function

As robotic capital (RK) was differentiated from traditional capital (Battisti et al., 2022), the capital part can be formulated as:

$$\mathbf{K= RK + TK}$$

8. Equation: The relation of robotic and traditional capital

Where TK means traditional capital. Extending the production function with the new element will look like this:

$$\mathbf{Y=F((RK+TK),L)}$$

9. Equation: Extending the production function

This is a simplistic form of the production function, merely for the presentation that there is competition between robots and labour. This aligns with my earlier findings that “labour and technology improvement are in competition with each other both in terms of volume and in terms of costs” (Guraly, 2020). The outcome of my field research also underlines these results: the managers confirmed that robotisation-related investments

[77] As mentioned earlier, MOFDI stands for outward foreign direct investment stock to manufacturing.

should be economically viable, e.g. the labour costs spared should balance the implementation and operational cost of robots.

The aforementioned theoretical considerations entail that the assumption that the robotisation in the V4 factories might negatively affect employment in these sites might be right. However, the statistics do not support this supposition; the participation rate has grown significantly in these countries in recent years. Besides, the significant increase in salaries in these countries implies that the competition from automation did not push workers to a position where the jobs can only be kept at the expense of salary reductions.

Narrowing the investigation to manufacturing, I observed the same tendencies. Theoretically, the more robots are utilised in a particular factory, the fewer production workers are necessary to prepare a specific product. However, the quantitative and qualitative analysis shows that the overall effect on employment in the V4 is not negative. First, the number of indirect workers is growing, as automation not only eliminates jobs but also creates new ones. These kinds of jobs are usually skilled, and many require an engineering degree. Second, despite the increase in productivity due to the growth in the production volume, the number of workers in the manufacturing industry is rising. Moreover, according to the interviews and quantitative results, the observation is that the pace of robotisation is still below the level of increase in the scarcity of workers in the V4. As expressed in the formula below:

$$\mathbf{D}^{\mathbf{L\Delta}}+\mathbf{D}^{\mathbf{Lnmr\Delta}} > \mathbf{D}^{\mathbf{Lmr\Delta}}$$

10. Equation: Changes in labour demand in the V4 manufacturing sector

Where,

$D^{L\Delta}$: Is the increase in the demand for workers in the manufacturing industry due to larger production volume,

$D^{Lnmr\Delta}$: Is the extra demand for non-manual workers due to robotisation,

$D^{Lmr\Delta}$: Is the decrease in the demand for manual workers due to robotisation.

Therefore, the labour situation in the V4 so far supports the "optimists" (for example, Autor, 2015) rather than the "pessimists" (Ford, 2015). It means that robotisation and worker substitution are in progress in the V4, but they do not increase unemployment due to a considerable increase in worker demand. On the contrary, as robotisation is connected to investments in manufacturing, and there is a growing production volume in the sector, my finding is that the increasing robotisation in the V4 supports employment. Consequently, **I *accept* the fourth hypothesis:** **the increase in the level of robotisation in the manufacturing sites of multinational companies in the V4 region impacts the number and type of workers employed.**

CONCLUSIONS AND RECOMMENDATIONS

Summary of main findings

This dissertation aimed to study how FDI-hosting catching-up countries, like the V4, developed during the era of swift robotisation. As was described, the Czech Republic, Hungary, Poland and Slovakia are trying to progress towards Western Europe, and the investments of large multinational companies in these countries' manufacturing sectors are a significant tool in reaching the desired development level. Robotisation, both indirectly via the headquarters of large multinationals and indirectly in their subsidiaries in the V4, impacts the development of these countries. This potential impact was analysed in four streams: foreign direct investment, technological upgrading, upgrading in global value chains and employment.

The study has a number of implications.

First, there is no evidence that the increasing robotisation in the production sites of the leading industrial countries negatively affects the investments in the manufacturing sector of the V4 region. The underlying assumption was that because of robotisation, the decreasing production costs in the major "FDI-sending" countries, particularly in Western Europe, might weaken the attractiveness of the V4 for investments. Both the quantitative and qualitative research results support the opposite: the manufacturing industry in the V4 is still an investment destination, and there are no signs of backshoring from these countries. Although a robotisation-related negative impact might be present, it is outbalanced by the other investment-related push and pull factors, which dominantly still favour the V4. Two factors are the proximity to Western Europe and the EU membership.

Second, I verified that there was a technological upgrading in the manufacturing industries in the V4. Large multinational companies are the primary enablers of this process via robotisation at their local production sites. Moreover, the increasing share of skilled workers at the expense of unskilled ones is another indication of upgrading. The results of my primary research conducted in interviews with managers and experts also support these findings.

Third, the expectation that in parallel with the technological upgrading, the subsidiaries in the V4 also upgrade in the GVCs was not confirmed. The statistics do not uphold my related supposition; according to the TiVA values, the V4 countries stagnated in GVC-related upgrading from 2010 to 2018. The literature supports the statistical evidence; most studies in the field show that production and assembly activities are dominantly the focus of the operations of the subsidiaries of the large multinationals in the V4. These activities are traditionally considered to possess a lower added value. Consequently, although there are some technological upgrading-related processes (e.g. increasing automation and a growing share of skilled workers), these activities are mainly in the production field. Albeit there are some examples of high-added value activities in the V4 (opening of new research centres, shared service centres, etc.), there is a counterbalancing effect from processes representing lower added value within the particular value chain.

Fourth, I found that the rise in robotisation in the subsidiaries in the V4 influences the workforce. However, this relation is not negative, as some researchers forecast, but positive. As robotisation in the region mainly results from investments, it goes conjointly with establishing new jobs. Therefore, even if robotisation might eliminate specific workplaces, the new investments and the growing production volumes are more powerful forces. What is observed via the field research is that automation is propelling development. Statistics also support this finding as despite the significant growth in robotisation, the unemployment rate is decreasing, and salaries are increasing in the V4. An equilibrium was found: the increase in robotisation keeps pace with the increase in employee-related costs.

As described above, the findings of this study present a mixed picture. On the one hand, there is some promising news for the V4, namely in investments, technological developments and employment. According to the quantitative and qualitative analyses at the macro and micro levels, despite the growing global robotisation tendencies, the Visegrad countries can maintain the inward foreign direct investments in their manufacturing sectors. Moreover, the robotisation in the subsidiaries of large multinational companies has a positive effect on the technological development of these countries. Finally, despite the upsurge in the number of robots deployed in these countries, the employees are not endangered: there is a scarcity of workers in the manufacturing industries, and the wages are growing. On the other hand, as described in this document, V4 countries did not upgrade in the global value chains as they still dominantly focus on industrial operations, which possess a lower added value in the global work distribution. This finding, combined with the fact that three of the four countries are highly embedded in GVCs, indicates a threat to the V4. Robotisation in itself might not be a threat, but the rising distance between production-related and knowledge-based activities can cause problems in the long term.

Based on the findings, I detected no evidence that the global robotisation tendencies negatively affect the catching-up of the V4 to the highly developed industrial countries, on the contrary, the conclusion is that **robotisation and the related automation processes, support the development of the V4 economies.**

Suggestions for future work

The world has become unstable recently. There are several, often conflicting courses in global politics and the economy, and powerful technological and social transformations are ongoing. Accordingly, revisiting this study's results periodically would be well-founded.

There are several other areas to explore, as introduced below.

First, there is an upgrading among robots, so a more detailed study of the independent variable of this thesis would be adequate. As mentioned during the field research, there is a new generation of lighter and cheaper robots in the market now, and their return on investment is probably much higher, and the payback period is quicker than it was in the case of the earlier generation of robust robots. Also, robots are increasingly collaborative, and the synergies between humans and machines can be explored. Finally, new technologies, artificial intelligence, and other solutions and techniques, like IOT, 3D printing, etc., change the technology landscape. Consequently, an update of the research with the inclusion of these elements might provide better insight into the forthcoming conversions.

Second, sustainability aspects change the production-related directions. The point might come soon where volume and growth will not be key performance indicators as humankind reaches its limits. This will challenge the current economic model of the V4 countries, which is still very much dependent on the volume aspects of FDI. Therefore, research on how the increasing focus on qualitative rather than quantitative aspects will affect the Visegrad Four countries may be a compelling research topic.

Third, the study's outcome was that the V4 countries are in a fortunate situation, and robotisation is not negatively impacting them. However, the underlying economic theories for robot and labour competition are valid. That means that some regions and some developing countries are either already negatively impacted, or these shifts in investing trends will detriment them in the near future. Studying the likely impact and inventing possible countermeasures can be another research direction.

Policy recommendations

The policy recommendations have three main directions: the first concerns labour, the second concerns robots, and the third concerns investments.

In terms of employees, the major problem, as explained in the study, is the lack of enough skilled experts. The manufacturing industries of the V4 need more workers, but what is more important than quantity is possessing the necessary skills. Besides the working environment, the required skills are changing. That means there is a need for a flexible, adaptive vocational training structure in the V4 countries. A modern educational system can also help maintain these countries' considerable global production position in the long term.

Regarding robots, and also in terms of general automation, Industry 4.0 tendencies, one of the main problems is the duality of the economy. There is already a significant gap between domestic small and medium-sized enterprises and multinational companies, although there are differences among the V4 countries. The main issue is that this gap is growing, and domestic firms do not have enough resources to invest in automation and robotisation. Accordingly, national programmes should support the technology upgrade of these companies, which in turn could enhance their upgrading in the global value chains.

In line with the researchers' findings in the region, the investment policies of these countries should be changed. One issue is the high integration into the global value chains for three countries (Czech Republic, Hungary and Slovakia) combined with a relatively low level of performance in terms of upgrading (especially in the case of Hungary and Slovakia). Large multinationals can relocate simple assembly-oriented activities fairly quickly. The fact that no backshoring process is ongoing in the V4 does not mean that it cannot take place in the future. The second issue is the lack of workforce for the manufacturing industry in the region. This is particularly true for the Czech Republic and Hungary, where the participation rate is the highest in the V4. The increased participation rate means these countries are practically close to full employment. These countries enjoy the "lucky momentum" that they already have enough investments in their country to maintain their economy. For both reasons, the investment policies should be altered, and the focus should shift from quantity to quality. The time has come when investment promotion agencies should be more selective about what kind of projects to support. As the head of the research centre of a multinational company in Hungary mentioned, now they concentrate much more on bringing more value-added activities to their subsidiary than on the increase in size: volume of work and number of employees. This is an example to be followed. Research and development centres and shared services should be at the centre of government policies more than increasing production capacity. Regarding production, the "forward escape," e.g., the support of automation and robotisation, brings more benefits than pure employee volume-oriented policies.

Moreover, the Visegrad Four countries should be more open to cross-border cooperation. On the one hand, it is a valid observation by decision-makers that there are substantial transformations in the automotive industry. For example, the development of battery production capacity can ensure the demand for the contribution of the V4 countries in this sector. However, not everything should be solved within the borders of a country. The region should develop together, and placing specific industries could be more optimal if the related considerations were broader. The V4 countries should switch from competition to cooperation.

Due to their growing disruptive nature, new automation developments provide an excellent opportunity to reconsider earlier policies. Decision makers should understand the "wind of change" and be ready to tailor policies and strategies to the quick transformation. Currently, the V4 countries seem to be winners of the ongoing automation and robotics processes. Actions should be implemented to ensure that this beneficial phase is prolonged.

Own Publications

<u>Published:</u>

Gurály, R. (2020). How Robotization is Changing the Production-Related Decisions? in *Contemporary global challenges in geopolitics, security policy and world economy*, Corvinus University of Budapest, 285-304

Dr. Kovács Z., & Gurály, R. (2021). A mesterséges intelligencia és egyéb felforgató technológiák vizsgálata, *Felderítő Szemle*, XX. Vol. 3., 47-62

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Gurály, R. (2024?). Made or invented in Hungary? Upgrading possibilities in light of global FDI tendencies. *KÖZ-GAZDASÁG* (expected publication: June 2024)

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APPENDIX

Appendix A: Macro-level Quantitative related tables

Industrial robots stock at the global level

Ind. robots stock	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021*
World total	917 874	944 823	994 264	1 035 301	1 020 731	1 059 162	1 153 097	1 235 389	1 332 212	1 472 088	1 631 650	1 837 559	2 125 276	2 439 543	2 730 661	3 035 000	3 477 000
increase vs previous year		3%	5%	4%	-1%	4%	9%	7%	8%	10%	11%	13%	16%	15%	12%	11%	15%

*2020 and 2021 data is rounded.

Industrial robots stock in the five main robotised countries

Ind. robots stock	2 005	2 006	2 007	2 008	2 009	2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019
China	11 557	17 327	23 908	31 787	37 312	52 290	74 317	96 924	132 784	189 358	256 463	349 470	501 185	649 447	782 725
Germany	126 294	132 594	139 980	144 643	144 133	148 256	157 241	161 988	167 579	175 768	182 632	189 305	200 497	215 795	223 387
Japan	373 481	351 658	356 240	355 562	332 720	307 698	307 201	310 508	304 001	295 829	286 554	287 323	297 215	318 110	354 878
South Korea	61 576	68 420	71 942	76 923	79 003	101 080	124 190	138 883	156 110	176 833	210 458	246 374	273 146	300 197	324 049
USA	139 984	150 725	160 632	168 489	166 183	173 174	180 893	190 321	203 187	219 434	234 245	250 479	262 058	285 014	299 674
Share of the world	78%	76%	76%	75%	74%	74%	73%	73%	72%	72%	72%	72%	72%	72%	73%

OFDI stock of selected eleven countries[79]

OFDI stock million USD	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	238 357	224 039	210 510	202 757	240 856	236 491	246 023	258 515	266 301
Belgium	565 311	554 624	582 582	599 380	707 828	544 143	657 896	683 679	640 010
Denmark	157 753	167 395	164 758	169 708	205 107	208 362	220 724	258 288	273 882
France	1 325 443	1 294 151	1 268 228	1 284 859	1 440 434	1 455 821	1 437 072	1 509 430	1 453 055
Germany	1 448 428	1 388 804	1 362 440	1 380 580	1 671 520	1 688 586	1 826 741	2 032 905	2 112 680
Italy	533 906	477 456	456 619	456 380	547 578	554 360	558 578	587 688	559 700
Japan	1 118 009	1 152 007	1 228 767	1 315 221	1 497 525	1 568 766	1 780 246	1 836 957	1 886 148
South Korea	237 932	242 792	276 100	296 641	343 089	383 983	433 671	488 180	515 435
Spain	572 343	519 308	505 765	496 605	575 744	549 085	575 836	558 669	531 613
Sweden	414 533	377 441	338 754	355 610	372 465	382 260	397 956	455 186	466 608
United States	6 254 171	6 320 124	6 059 272	6 395 424	7 865 017	6 370 722	7 585 337	8 225 887	9 765 936
Total	**12 866 186**	**12 718 141**	**12 453 795**	**12 953 165**	**15 467 163**	**13 942 579**	**15 720 080**	**16 895 384**	**18 471 368**

MOFDI stock of selected eleven countries[80]

MOFDI stock million USD	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	47 345	39 741	38 175	39 284	46 703	49 252	52 714	58 632	64 539
Belgium	74 061	93 520	112 979	119 590	141 909	139 033	153 160	153 400	171 631
Denmark	51 402	48 342	41 481	40 866	47 837	46 440	52 083	36 396	38 909
France	373 133	389 846	373 918	380 504	412 138	450 559	425 862	445 299	466 306
Germany	224 503	216 149	195 268	207 733	252 445	261 751	284 174	294 883	305 592
Italy	129 729	115 493	118 516	125 553	154 183	155 569	159 565	172 806	184 169
Japan	507 354	521 497	535 640	554 006	617 585	625 113	729 084	708 229	715 430
South Korea	99 154	96 769	102 207	110 985	135 267	135 519	162 087	178 836	195 585
Spain	110 848	92 569	94 196	68 315	71 207	67 146	66 271	67 578	68 885
Sweden	178 194	165 442	152 650	143 850	159 329	166 549	165 334	175 885	196 982
United States	623 700	654 335	693 847	687 625	806 448	738 377	786 581	864 386	912 625
Total	**2 419 423**	**2 433 703**	**2 458 877**	**2 478 311**	**2 845 051**	**2 835 308**	**3 036 915**	**3 156 330**	**3 320 653**

[79] Grey values were not available therefore are estimated.

[80] Grey values were not available therefore are estimated.

MOFDI/OFDI comparison

MOFDI/OFDI	2013	2014	2015	2016	2017	2018	2019	2020	2021
MOFDI growth rate		0,6%	1,0%	0,8%	14,8%	-0,3%	7,1%	3,9%	5,2%
OFDI growth rate		-1,2%	-2,1%	4,0%	19,4%	-9,9%	12,7%	7,5%	9,3%
MOFDI/OFDI ratio	18,8%	19,1%	19,7%	19,1%	18,4%	20,3%	19,3%	18,7%	18,0%

MOFDI Trend and OFDI Trend comparison

MOFDI/OFDI Trend	2013	2014	2015	2016	2017	2018	2019	2020	2021
MOFDI growth rate		2,0%	2,6%	3,2%	3,8%	4,4%	5,0%	5,6%	6,2%
OFDI growth rate		0,1%	1,5%	2,9%	4,3%	5,7%	7,1%	8,5%	9,9%
MOFDI/OFDI ratio	19,3%	19,3%	19,2%	19,1%	19,1%	19,0%	18,9%	18,8%	18,8%

Germany: Actual Robotisation and Actual MOFDI/OFDI Numbers

Year	Robots (actual)	MOFDI/OFDI	Robots change %	MOFDI/OFDI %
2005	126 294			
2006	132 594		5,0%	
2007	139 980		5,6%	
2008	144 643		3,3%	
2009	144 133		-0,4%	
2010	148 256		2,9%	
2011	157 241		6,1%	
2012	161 988		3,0%	
2013	167 579	15,50%	3,5%	
2014	175 768	15,56%	4,9%	0,4%
2015	182 632	14,33%	3,9%	-7,9%
2016	189 305	15,05%	3,7%	5,0%
2017	200 497	15,10%	5,9%	0,4%
2018	215 795	15,50%	7,6%	2,6%
2019	223 387	15,56%	3,5%	0,4%
2020		14,51%		-6,8%
2021		14,46%		-0,3%

Germany: Robotisation Trend and MOFDI Trend/OFDI Trend Numbers

Year	Robots (trend)	MOFDI(trend)/OFDI(trend)	Robots change %	MOFDI/OFDI %
2013	165 137	15,48%		
2014	174 613	15,34%	5,7%	-0,9%
2015	184 090	15,23%	5,4%	-0,8%
2016	193 566	15,13%	5,1%	-0,7%
2017	203 043	15,04%	4,9%	-0,6%
2018	212 519	14,96%	4,7%	-0,5%
2019	221 996	14,89%	4,5%	-0,5%

South Korea: Actual Robotisation and Actual MOFDI/OFDI Numbers

Year	Robots (actual)	MOFDI/OFDI (actual)	Robots change %	MOFDI/OFDI %
2005	61 576			
2006	68 420		11,1%	
2007	71 942		5,1%	
2008	76 923		6,9%	
2009	79 003		2,7%	
2010	101 080		27,9%	
2011	124 190		22,9%	
2012	138 883		11,8%	
2013	156 110	41,67%	12,4%	
2014	176 833	39,86%	13,3%	-4,4%
2015	210 458	37,02%	19,0%	-7,1%
2016	246 374	37,41%	17,1%	1,1%
2017	273 146	39,43%	10,9%	5,4%
2018	300 197	35,29%	9,9%	-10,5%
2019	324 049	37,38%	7,9%	5,9%
2020		36,63%		-2,0%
2021		37,95%		3,6%

South Korea: Robotisation Trend and MOFDI Trend/OFDI Trend Numbers

Year	Robots (trend)	MOFDI(trend)/OFDI(trend)	Robots change %	MOFDI/OFDI %
2013	153 892	40,17%		
2014	182 936	39,31%	18,9%	-2,2%
2015	211 980	38,67%	15,9%	-1,6%
2016	241 024	38,19%	13,7%	-1,3%
2017	270 068	37,80%	12,1%	-1,0%
2018	299 112	37,49%	10,8%	-0,8%
2019	328 156	37,23%	9,7%	-0,7%

France: Actual Robotisation and Actual MOFDI/OFDI Numbers

Year	Robots (actual)	MOFDI/OFDI	Robots change %	MOFDI/OFDI %
2005	30236,00	0,29		
2006	32110,00	0,27	0,06	-0,06
2007	33462,00	0,27	0,04	-0,01
2008	34370,00	0,29	0,03	0,06
2009	34099,00	0,26	-0,01	-0,11
2010	34495,00	0,24	0,01	-0,06
2011	34461,00	0,26	0,00	0,08
2012	33624,00	0,29	-0,02	0,10
2013	32301,00	0,28	-0,04	-0,01
2014	32233,00	0,30	0,00	0,07
2015	32161,00	0,29	0,00	-0,02
2016	33384,00	0,30	0,04	0,00
2017	35321,00	0,29	0,06	-0,03
2018	38079,00	0,31	0,08	0,08
2019	42054,00	0,30	0,10	-0,04
2020		0,30		0,00
2021		0,32		0,09

France: Robotisation Trend and MOFDI Trend/OFDI Trend Numbers

Year	Robots (trend)	MOFDI(trend)/OFDI(trend)	Robots change %	MOFDI/OFDI %
2005	31 375	25,61%		
2006	31 772	26,12%	1,3%	2,0%
2007	32 170	26,58%	1,3%	1,8%
2008	32 568	27,00%	1,2%	1,6%
2009	32 966	27,39%	1,2%	1,4%
2010	33 364	27,74%	1,2%	1,3%
2011	33 762	28,06%	1,2%	1,2%
2012	34 159	28,36%	1,2%	1,1%
2013	34 557	28,64%	1,2%	1,0%
2014	34 955	28,90%	1,2%	0,9%
2015	35 353	29,14%	1,1%	0,8%
2016	35 751	29,36%	1,1%	0,8%
2017	36 148	29,57%	1,1%	0,7%
2018	36 546	29,77%	1,1%	0,7%
2019	36 944	29,96%	1,1%	0,6%

The input table for the regression analysis

Country	year	robotisation growth	MOFDI/OFDI ratio	Austria	Belgium	Denmark	France	Germany	Italy	Japan	South Korea	Spain	Sweden	United States
Austria	2013	1,00	19,86%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2014	1,03	17,74%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2015	1,12	18,13%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2016	1,28	19,37%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2017	1,45	19,39%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2018	1,59	20,83%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Austria	2019	1,71	21,43%	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2013	1,00	13,10%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2014	1,00	16,86%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2015	1,00	19,39%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2016	1,07	19,95%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2017	1,15	20,05%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2018	1,20	25,55%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Belgium	2019	1,26	23,28%	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2013	1,00	32,58%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2014	1,08	28,88%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2015	1,15	25,18%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2016	1,24	24,08%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2017	1,34	23,32%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2018	1,39	22,29%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Denmark	2019	1,43	23,60%	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2013	1,00	28,15%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2014	1,00	30,12%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2015	1,00	29,48%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2016	1,03	29,61%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2017	1,09	28,61%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2018	1,18	30,95%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
France	2019	1,30	29,63%	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2013	1,00	15,50%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2014	1,05	15,56%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2015	1,09	14,33%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2016	1,13	15,05%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2017	1,20	15,10%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2018	1,29	15,50%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Germany	2019	1,33	15,56%	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
Italy	2013	1,00	24,30%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2014	1,01	24,19%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2015	1,04	25,96%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2016	1,05	27,51%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2017	1,09	28,16%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2018	1,17	28,06%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Italy	2019	1,26	28,57%	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Japan	2013	1,00	45,38%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2014	0,97	45,27%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2015	0,94	43,59%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2016	0,95	42,12%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2017	0,98	41,24%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2018	1,05	39,85%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
Japan	2019	1,17	40,95%	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00
South Korea	2013	1,00	41,67%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2014	1,13	39,86%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2015	1,35	37,02%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2016	1,58	37,41%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2017	1,75	39,43%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2018	1,92	35,29%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
South Korea	2019	2,08	37,38%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
Spain	2013	1,00	19,37%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2014	1,00	17,83%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2015	1,06	18,62%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2016	1,10	13,76%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2017	1,15	12,37%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2018	1,25	12,23%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Spain	2019	1,31	11,51%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
Sweden	2013	1,00	42,99%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2014	1,06	43,83%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2015	1,17	45,06%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2016	1,25	40,45%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2017	1,30	42,78%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2018	1,34	43,57%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Sweden	2019	1,40	41,55%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
United States	2013	1,00	9,97%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2014	1,08	10,35%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2015	1,15	11,45%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2016	1,23	10,75%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2017	1,29	10,25%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2018	1,40	11,59%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
United States	2019	1,47	10,37%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00

Detailed Results of the Regression Analysis (SPSS outputs)

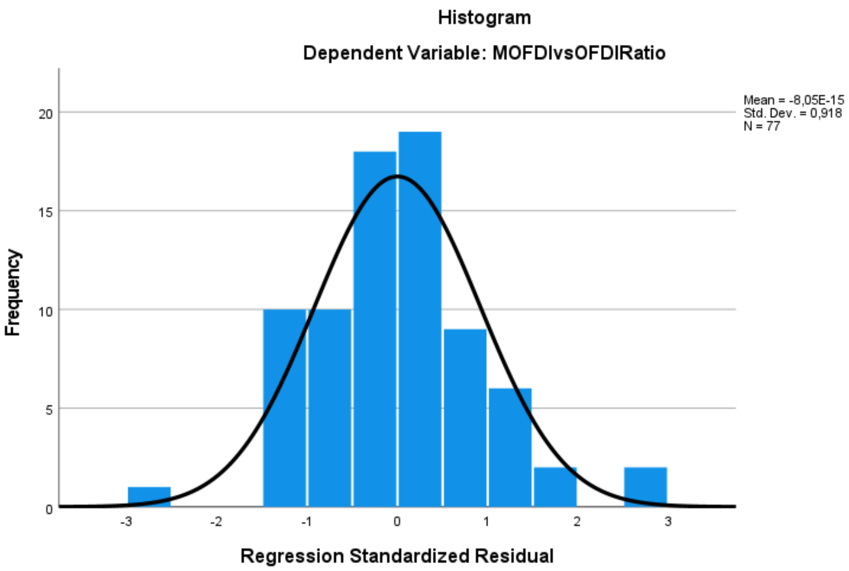
Descriptive Statistics			
	Mean	Std. Deviation	N
MOFDIvsOFDIRatio	26,00%	11,06%	77
Year	2016,00	2,013	77
RobotisationGrowth	1,19	0,22	77

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,981[a]	**0,962**	0,955	2,33%
a. Predictors: (Constant), Sweden, Year, Spain, SouthKorea, Japan,				
b. Dependent Variable: MOFDIvsOFDIRatio				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8945,218	12	745,435	136,865	**,000[b]**
	Residual	348,576	64	5,447		
	Total	9293,794	76			
a. Dependent Variable: MOFDIvsOFDIRatio						
b. Predictors: (Constant), Sweden, Year, Spain, SouthKorea, Japan, Italy, Germany,						

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-59,535	499,470		-0,119	0,905
	Year	0,036	0,249	0,007	0,146	0,885
	RobotisationGrowth	-2,444	2,860	-0,050	-0,854	**0,396**
	Austria	9,055	1,268	0,237	7,139	0,000
	Belgium	8,729	1,307	0,228	6,676	0,000
	Denmark	15,024	1,247	0,393	12,043	0,000
	France	18,472	1,317	0,483	14,029	0,000
	Germany	4,360	1,267	0,114	3,441	0,001
	Italy	15,646	1,314	0,409	11,905	0,000
	Japan	31,400	1,405	0,822	22,354	0,000
	SouthKorea	28,376	1,532	0,743	18,528	0,000
	Spain	4,153	1,286	0,109	3,230	0,002
	Sweden	32,171	1,248	0,842	25,770	0,000
a. Dependent Variable: MOFDIvsOFDIRatio						

Correlations				
		MOFDIvsOFDIRatio	Year	RobotisationGrowth
Pearson Correlation	MOFDIvsOFDIRatio	1,000	-0,026	0,031
	Year	-0,026	1,000	0,661
	RobotisationGrowth	**0,031**	0,661	1,000



Global GVC trend-related tables

DVA reimport in Exports %	2010	2018	difference
China	0,5%	0,7%	0,2%
Germany	0,8%	0,9%	0,1%
Japan	0,2%	0,2%	0,0%
South Korea	0,3%	0,3%	0,0%
USA	0,6%	0,6%	0,0%

Non-GVC Exports %	2010	2018	difference
China	62,8%	62,8%	0,0%
Germany	55,1%	52,8%	-2,3%
Japan	59,1%	57,1%	-2,0%
South Korea	44,9%	46,2%	1,3%
USA	65,7%	63,8%	-1,9%

Macroeconomic indicators in the Visegrad Four Group

GDP growth %	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Germany	0,4	2,2	1,5	2,2	2,7	1	1,1	-3,7	2,6	1,8
EU (27)	-0,1	1,6	2,3	2	2,8	2,1	1,8	-5,6	5,4	3,5
Czech Republic	0	2,3	5,4	2,5	5,2	3,2	3	-5,5	3,6	2,4
Hungary	1,8	4,2	3,7	2,2	4,3	5,4	4,9	-4,5	7,1	4,6
Poland	0,9	3,8	4,4	3	5,1	5,9	4,5	-2	6,8	4,9
Slovakia	0,6	2,7	5,2	1,9	2,9	4	2,5	-3,4	3	1,7

Export (% of GDP)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	66%	71%	76%	76%	82%	81%	79%	79%	77%	74%	70%	73%
Germany	43%	45%	46%	45%	46%	47%	46%	47%	47%	47%	43%	47%
European Union	40%	43%	45%	45%	46%	47%	47%	48%	49%	49%	46%	50%
Hungary	81%	86%	86%	85%	87%	88%	86%	86%	84%	82%	79%	82%
Poland	40%	43%	44%	46%	46%	47%	50%	52%	53%	53%	53%	58%
Slovak Republic	77%	84%	91%	93%	91%	92%	93%	95%	96%	92%	85%	94%

Manufacturing VA (% of GDP)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	21%	22%	22%	22%	24%	24%	24%	24%	23%	23%	21%	21%
Germany	20%	20%	20%	20%	20%	20%	21%	20%	20%	20%	19%	19%
European Union	15%	15%	15%	14%	15%	15%	15%	15%	15%	15%	15%	15%
Hungary	18%	18%	18%	19%	19%	20%	20%	19%	19%	17%	17%	17%
Poland	16%	16%	17%	16%	17%	18%	18%	17%	17%	17%	16%	17%
Slovak Republic	18%	18%	18%	17%	19%	20%	19%	18%	19%	20%	18%	20%

participation rate	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	65,0	65,7	66,5	67,7	69,0	70,2	72,0	73,6	74,8	75,1	74,4	74,4
Hungary	54,9	55,4	56,7	58,1	61,8	63,9	66,5	68,2	69,2	70,1	69,7	73,1
Poland	58,9	59,3	59,7	60,0	61,7	62,9	64,5	66,1	67,4	68,2	68,7	70,3
Slovak Republic	58,8	59,3	59,7	59,9	61,0	62,7	64,9	66,2	67,6	68,4	67,5	69,4

labour cost index	2015	2016	2017	2018	2019	2020	2021	2022
Czech Republic	100	103	107	113	118	126	128	134
Hungary	100	104	108	111	114	122	124	139
Poland	100	103	104	106	111	118	118	130
Slovak Republic	100	103	107	112	118	123	126	135
Germany	100	101	102	105	109	112	112	117
European Union	100	101	101	103	105	109	109	113

Table Related to the Inward Foreign Direct Investment Trends in the V4

IFDI stock (million USD)	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	134 085	121 512	116 628	121 855	155 994	164 225	171 334	195 240	200 587
Hungary	109 150	100 411	86 254	82 701	92 556	92 067	94 223	102 129	104 900
Poland	229 167	211 951	183 869	186 735	238 990	231 603	241 621	257 586	271 915
Slovakia	58 022	49 738	46 016	47 592	59 510	59 857	60 601	64 295	59 369
V4 total	**530 424**	**483 612**	**432 767**	**438 883**	**547 050**	**547 752**	**567 779**	**619 250**	**636 771**
V4 average	132 606	120 903	108 192	109 721	136 763	136 938	141 945	154 813	159 193
V4 average (trend)	113 266	118 313	123 359	128 406	133 452	138 499	143 546	148 592	153 639
Growth rate		4,5%	4,3%	4,1%	3,9%	3,8%	3,6%	3,5%	3,4%

Tables Related to the Inward Foreign Direct Investment Trends to the Manufacturing Industry in the V4

MIFDI stock (million USD) in the V4	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	43 343	40 624	38 352	38 459	45 506	46 661	48 417	52 959	51 462
Hungary	23 392	24 932	9 329	24 495	39 237	37 851	40 084	44 985	51 031
Poland	68 668	61 909	60 202	59 237	77 744	72 799	79 352	82 834	89 115
Slovakia*	18 772	16 621	15 302	15 358	19 091	15 210	19 844	20 347	20 850
V4 total	**154 175**	**144 086**	**123 185**	**137 549**	**181 578**	**172 521**	**187 697**	**201 125**	**212 458**
V4 average	38 544	36 022	30 796	34 387	45 395	43 130	46 924	50 281	53 115
V4 average (trend)	32 595	34 963	37 331	39 698	42 066	44 434	46 801	49 169	51 537
growth rate		7,3%	6,8%	6,3%	6,0%	5,6%	5,3%	5,1%	4,8%
Germany*	55 188	43 490	42 703	40 651	61 804	59 265	54 408	63 315	72 222

*Values are estimated.

population (million) in the V4 and in Germany	2013	2014	2015	2016	2017	2018	2019	2020
Czech Republic	11	11	11	11	11	11	11	11
Hungary	10	10	10	10	10	10	10	10
Poland	39	38	38	38	38	38	38	38
Slovakia	5	5	5	5	5	5	5	5
V4 total	64	64	64	64	64	64	64	64
Germany	81	81	82	82	83	83	83	83

MIFDI stock/capita in USD	2013	2014	2015	2016	2017	2018	2019	2020
Czech Republic	4 124	3 860	3 638	3 640	4 297	4 391	4 538	4 949
Hungary	2 364	2 527	948	2 496	4 009	3 872	4 102	4 614
Poland	1 783	1 609	1 566	1 542	2 023	1 895	2 067	2 160
Slovakia	3 468	3 067	2 821	2 828	3 510	2 792	3 638	3 727
V4 avegage	2 397	2 241	1 917	2 141	2 827	2 685	2 920	3 130
Germany	684	537	523	494	748	715	655	761

FDI stock ratios	2013	2014	2015	2016	2017	2018	2019	2020	2021
11 countries MOFDI/OFDI	18,8%	19,1%	19,7%	19,1%	18,4%	20,3%	19,3%	18,7%	18,0%
V4 MIFDI/IFDI	29,1%	29,8%	28,5%	31,3%	33,2%	31,5%	33,1%	32,5%	33,4%
11 countries MOFDI/OFDI Trend	19,3%	19,3%	19,2%	19,1%	19,1%	19,0%	18,9%	18,8%	18,8%
V4 MIFDI/IFDI Trend	29,1%	29,6%	30,2%	30,8%	31,4%	31,9%	32,5%	33,1%	33,7%

V4 GVC trend-related tables

FVA in Exports %	2010	2018	difference
Czech Republic	40,0%	42,2%	2,2%
Hungary	48,3%	46,3%	-2,0%
Poland	29,7%	31,0%	1,3%
Slovak Republic	44,5%	48,0%	3,5%

DVA GVC in Exports %	2010	2018	difference
Czech Republic	18,0%	19,7%	1,7%
Hungary	13,7%	17,0%	3,3%
Poland	20,7%	22,6%	1,9%
Slovak Republic	17,9%	19,0%	1,1%

DVA reimport in Exports %	2010	2018	difference
Czech Republic	0,2%	0,3%	0,1%
Hungary	0,1%	0,1%	0,0%
Poland	0,2%	0,2%	0,0%
Slovak Republic	0,1%	0,2%	0,1%

Non-GVC Exports %	2010	2018	difference
Czech Republic	41,8%	37,8%	-4,0%
Hungary	37,9%	36,6%	-1,3%
Poland	49,4%	46,2%	-3,2%
Slovak Republic	37,5%	32,8%	-4,7%

Research and development-related spending in the V4 and Germany

R&D spending (% of GDP)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Germany	2,73	2,81	2,88	2,84	2,88	2,93	2,94	3,05	3,11	3,17	3,13	3,13
EU	1,97	2,02	2,08	2,1	2,11	2,12	2,12	2,15	2,19	2,22	2,3	2,26
Czech Republic	1,33	1,54	1,77	1,88	1,96	1,92	1,67	1,77	1,9	1,93	1,99	2,0
Hungary	1,13	1,18	1,25	1,38	1,34	1,34	1,18	1,32	1,51	1,47	1,59	1,65
Poland	0,72	0,75	0,88	0,88	0,94	1	0,96	1,03	1,21	1,32	1,39	1,44
Slovakia	0,61	0,65	0,79	0,82	0,88	1,16	0,79	0,88	0,84	0,82	0,9	0,93

R&D spending (annual growth rate)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Germany	2,9%	2,5%	-1,4%	1,4%	1,7%	0,3%	3,7%	2,0%	1,9%	-1,3%	0,0%
EU	2,5%	3,0%	1,0%	0,5%	0,5%	0,0%	1,4%	1,9%	1,4%	3,6%	-1,7%
Czech Republic	15,8%	14,9%	6,2%	4,3%	-2,0%	-13,0%	6,0%	7,3%	1,6%	3,1%	0,5%
Hungary	4,4%	5,9%	10,4%	-2,9%	0,0%	-11,9%	11,9%	14,4%	-2,6%	8,2%	3,8%
Poland	4,2%	17,3%	0,0%	6,8%	6,4%	-4,0%	7,3%	17,5%	9,1%	5,3%	3,6%
Slovakia	6,6%	21,5%	3,8%	7,3%	31,8%	-31,9%	11,4%	-4,5%	-2,4%	9,8%	3,3%

Labour productivity

labour productivity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Czech Republic	77,9	77,8	76,9	77,8	80,0	80,5	80,6	82,5	83,8	85,7	86,2	85,6
Germany	104,7	105,9	105,1	104,5	106,5	105,3	106,1	106,3	105,9	103,8	105,1	104,0
Hungary	74,3	75,0	73,4	73,4	71,8	71,4	68,2	67,9	69,4	70,8	71,8	72,3
Poland	69,8	71,9	73,5	73,0	73,1	74,5	73,9	74,8	76,9	79,8	82,0	81,9
Slovak Republic	85,2	82,7	83,7	84,4	84,6	83,9	77,4	74,1	73,3	73,6	75,2	74,0
European Union	100,	100,	100,	100,	100,	100,	100,	100,	100,	100,	100,	100,

Data in %, the EU average is 100.

Robotisation in the V4

Ind. robots stock	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Czech Republic	1 971	2 472	3 258	3 978	4 160	4 462	5 890	6 830	8 097	9 543	11 238	13 049	15 429	17 603	19 391
Hungary	458	592	772	1 014	1 207	1 406	2 347	3 301	3 829	4 302	4 784	5 424	7 711	8 481	9 212
Poland	846	1 213	1 704	2 548	2 805	3 321	3 965	4 590	5 262	6 401	8 136	9 693	11 360	13 632	15 769
Slovakia	576	596	677	860	1 068	1 870	2 210	2 294	3 572	3 891	4 378	6 071	7 093	7 796	8 326
V4 total	**3 851**	**4 873**	**6 411**	**8 400**	**9 240**	**11 059**	**14 412**	**17 015**	**20 760**	**24 137**	**28 536**	**34 237**	**41 593**	**47 512**	**52 698**
Germany	126 294	132 594	139 980	144 643	144 133	148 256	157 241	161 988	167 579	175 768	182 632	189 305	200 497	215 795	223 387

Robotisation per million inhabitants	2013	2014	2015	2016	2017	2018	2019
Czech Republic	770	907	1 066	1 235	1 457	1 657	1 817
Hungary	387	436	486	553	788	868	943
Poland	137	166	212	252	296	355	411
Slovakia	660	718	807	1 118	1 304	1 431	1 527
V4 average	323	375	444	533	647	739	820
Germany	2 078	2 170	2 236	2 299	2 426	2 603	2 688

Appendix B: Micro-level Quantitative Analysis related tables

Mercedes Group financial indicators

millions of euros	2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019	2 020
Revenue	97 761	106 540	114 297	117 982	129 872	149 467	153 261	164 154	167 362	172 745	121 778
EBIT	7 274	8 755	8 820	10 815	10 752	13 186	12 902	14 348	11 132	4 329	6 091
Profit before income taxes	6 628	8 449	8 116	10 139	10 173	12 744	12 574	13 967	10 595	3 830	5 957
Personnel expenses	16 454	17 424	18 002	18 753	19 607	20 949	21 141	22 186	22 432	22 657	21 848

Mercedes Group employee-related data

	2 016	2 017	2 018	2 019	2 020
Number of employees	282 488	289 321	298 683	298 655	288 481
Number of employees (industrial and administrative)*	266 139	272 209	281 416	282 505	276 017
Industrial workers	142 223	145 330	151 026	151 005	148 569
Non-industrial workers	123 916	126 879	130 390	131 500	127 448

*Trainees and interns are not counted.

Kecskemét Factory financial indicators

Actual values in million euro	2014	2015	2016	2017	2018	2019	2020	2021
Tangible Assets	768	723	791	922	1117	1143	1042	1114
Revenue	2 809	3 401	3 403	3 554	3 561	3 687	3 412	3 095
Profit before taxes	64	67	67	79	92	98	42	75

Kecskemét Factory employee-related data

	2016	2017	2018	2019	2020	2021
Number of staff	3 555	3 550	4 281	4 772	4 213	4 535
manual workers	2 867	2 819	3 291	3 607	3156	3 386
non manual workers	688	731	990	1 165	1057	1 149

Mercedes employee growth

Employee related expenses/employee	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Mercedes Group (thousand euro)	63,75	65,19	65,56	68,10	70,06	73,62	74,84	76,68	75,10	75,86	75,73	
Kecskemét Factory (thousand euro)							19,97	22,25	21,96	22,84	23,02	23,81
Mercedes Group (annual growth rate %)		2,3%	0,6%	3,9%	2,9%	5,1%	1,7%	2,5%	-2,1%	1,0%	-0,2%	
Kecskemét Factory (annual growth rate %)								11,4%	-1,3%	4,0%	0,8%	3,4%
Mercedes Group 2020/2016											1,2%	
Kecskemét Factory 2020/2016											15,3%	

Procter & Gamble global financial results

	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019	2 020	2 021	2022*
Revenue (million EUR)	56 127	66 465	64 595	54 387	63 282	58 828	57 018	57 465	59 686	63 405	64 072	77 251
Profit before taxes (million EUR)	10 379	10 155	11 391	9 875	9 850	12 044	11 619	11 458	5 352	14 150	14 827	17 336
Number of staff	129 000	126 000	121 000	118 000	110 000	105 000	95 000	92 000	97 000	99 000	101 000	106 000

Euro values are converted from USD using the ECB conversion rate and the date of the close of the financial year.

*P&G financial period closes on the 30st of June each year.

Procter & Gamble Hungary financial results

	2011	2012	2013	2014	2015	2016
Revenue (million EUR)	57,9	61,4	67,5	76,8	85,2	99,5
Profit before taxes (million EUR)	6,3	8,3	8,6	8,4	9,0	11,4
Personnel costs (million EUR)	16,3	18,4	20,9	23,6	24,7	28,7

	2017	2018	2019	2020	2021	2022*
Revenue (million EUR)	143,6	138,7	158,4	160,1	165,1	173,4
Profit before taxes (million EUR)	16,3	13,8	17,1	15,8	18,7	19,6
Personnel costs (million EUR)	36,1	36,3	39,1	41,2	46,5	39,4

Rate conversion was made using the MNB rate at the end of the financial year.

*P&G financial period closes on the 30st of June each year.

Procter & Gamble Hungary employee-related numbers

	2011	2012	2013	2014	2015	2016
Number of staff	723	768	798	906	982	1063
manual workers	563	591	606	667	745	812
non manual workers	160	177	192	239	237	251

	2017	2018	2019	2020	2021	2022*
Number of staff	1200	1222	1251	1370	1492	1534
manual workers	911	924	955	1048	1132	1161
non manual workers	289	298	296	322	360	373