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# Department of Economic Policy

## Working Paper Series

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### **Potential Risk of Automation for Employment in Slovakia: A District- and Industry-Level Analysis**

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# Potential Risk of Automation for Employment in Slovakia: A District- and Industry-Level Analysis<sup>1</sup>

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## Abstract

The aim of this paper is to examine the potential impacts of automation and digitalisation on the Slovak labour market, which, according to several studies, belongs to a group of countries with the highest risk. To quantify the share of employment at a high risk of automation, we use detailed employment data and automatability estimates (or substitutional potentials) for individual occupations according to three different methodologies: by Frey and Osborne (2013), Dengler and Matthes (2018), and Mihaylov and Tijdens (2019). In 2019, depending on the approach taken, the share of employment in Slovakia at a high risk of automation ranged from about 20 to 47%. Districts at the highest risk of automation include Kysucké Nové Mesto, Bytča, Myjava, Skalica and Krupina, while districts with the lowest share of employment at risk are Svidník, Levoča, Ružomberok, Košice I and Trebišov. A key point is that technological progress is not likely to increase the existing regional differences in Slovakia or have a greater impact on districts with high unemployment. Other findings show that employees with a lower income face a higher risk of losing their job as a result of technological progress. Industries with the largest share of employment at a very high risk include many manufacturing industries, as well as wholesale and retail trade. In terms of occupations, mechanical machinery assemblers and electrical equipment assemblers face the highest risk. Regarding trade, occupations potentially facing a high risk include shop sales assistants, cashiers, ticket clerks, commercial sales representatives, and stock clerks.

**Keywords:** Automation, digitalisation, employment, occupations, regions, Slovakia

**JEL Classification:** J21, J23, O33

## Introduction

The vision of a fully automated and integrated production process from the very beginning up until the distribution of products is no longer a far-off dream. Production halls with a minimum number of workers and the use of robots and 3D printers, which require only a minimum amount of on-the-spot physical labour for their operation, are increasingly becoming a reality, and autonomous conveyor systems are also commonly used. This raises questions and concerns about the future of work, and quite naturally so. In response to this, several authors deal with the potential impacts of technological progress and estimate the probabilities of individual tasks or even whole occupations becoming automated in the near future. Literature already offers a wide spectrum of estimates ranging from positive and neutral to strongly negative effects on the overall employment. Some of the first authors to start the discussion on the future of work were undoubtedly Frey and Osborne (2013). Based on expert assessments, they estimate the probability with which individual occupations will become automated over the next two to three decades. Their estimates suggest a relatively high percentage of U.S. jobs facing a high risk of automation (around 47%). Several other

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authors used these estimates to calculate the potential impacts on the labour markets of other countries.

In other papers, this methodology is used with various adjustments to account for the fact that not all workers in a given occupation have the same employment profile, and that positions may not necessarily disappear entirely. There is also a possibility that only some of the tasks in a given occupation will transform or cease to exist. Work automatability estimates for Slovakia differ depending on the methods used by individual authors. The share of employment facing a high risk of automation is estimated in the range of 11 to 55%. What these studies have in common is that they categorise Slovakia among labour markets at the highest risk of automation.

The aim of this paper is to examine the impacts of automation on the Slovak labour market using automatability estimates for individual occupations by three different pairs of authors (Frey and Osborne (2013), Dengler and Matthes (2018), and Mihaylov and Tjidsens (2019)). The most important added value of this analysis is the fact that detailed employment and wage data are used. By applying three different methodologies to such detailed data, we obtain automation risk estimates for Slovak jobs which are as accurate as possible, including on the level of regions, industries or specific occupations. In the case of each of these approaches, it is possible to point out the advantages and disadvantages associated with their use. They are specified in the methodology and data section.

The paper is structured as follows: The first chapter includes an overview of literature dealing with the implications of technological progress for the future of work. The second chapter provides information on the data used and the research methodology. The empirical section first deals with the calculated shares of Slovak employment at a high risk of automation, and then examines whether the substitution potentials estimated by Dengler and Matthes (2018) have already managed to manifest themselves in the Slovak economy in the form of real changes in employment and wages at least to some minor extent. In the second section, the risk for labour markets is analysed on the regional level, and conclusions regarding the ability of automation and digitalisation to increase or decrease the existing regional differences in Slovakia are drawn. The subsequent section includes a discussion on the implications of automation for income inequalities. The last section of the third chapter includes a detailed analysis of industry and occupational aspects of employees at risk. The last chapter summarises the results of the conducted research.

## **1. Literature Review**

The last decade saw the publication of several studies the authors of which estimate that automation and other new technologies have a potential to significantly disrupt the labour market in the near future. The discussion on the future of work in the context of emerging technologies was kick-started by Frey and Osborne (2013), who estimate that as much as 47% U.S. jobs are at a high risk of automation. Their methodology is based on using expert assessments to estimate the probability with which each of the 702 occupations will become automated in the next two to three decades. Several other authors used these estimates to calculate the potential impacts on the labour markets of other countries. In the case of Finland and Norway, around 35% of jobs face a high risk of automation (Pajarinen and Rouvinen, 2014; Pajarinen et al., 2015). Moreover, in the case of both countries, the authors obtained results suggesting that automation poses a higher risk for jobs

that are lower-paid and have lower education requirements. It seems that the German labour market faces the highest potential risk of automation – as many as 59% of jobs fall into the category with a high probability of automation (Brzeski and Burk, 2015). In the case of Ireland, Crowley and Doran (2019) perform this analysis on the level of cities, and their estimates range from 26 to 58% (with an average of 44%).

One of the most recent contributions is the estimate for Austria. Haiss et al. (2020) calculated the value of 40% and came up with their own interpretation of the result. They claim that in reality, only a small proportion of occupations falling into the high-risk category will be completely automated. However, the vast majority of these occupations will go through significant changes in the requirements for the competences, skills and education of workers and in the tasks performed as a part of these occupations. The authors also estimate that the implementation of new technologies will affect women more negatively than men. To get the most reliable results possible, it is key for this methodology that detailed employment data are used. Although compared to the above-mentioned studies, Bowles (2014) worked with more aggregated employment data, his results can be used at least as a guideline to compare the risks for the labour markets of individual EU countries. The Romanian labour market faces the highest risk of automation (roughly 62%). In contrast, automation represents the lowest risk for workers in Sweden (around 47%). For Slovakia, the author estimates that roughly 55% of jobs are at a high risk of automation. This is almost identical with the average for all EU member states (54%).

The results of the microeconomic analysis by Fossen and Sorgner (2018) indicate that workers in occupations facing a higher risk of automation are already changing their profession or becoming unemployed. However, it is questionable whether these movements are voluntary or involuntary. The authors are inclined to go for the optimistic interpretation of the results of their research – workers, in order to avoid future unemployment, are already moving to other occupations facing a lower risk of automation. However, the question whether workers really move to occupations facing a lower risk of automation was beyond the scope of their research. Thus, it is only a hypothesis.

Based on the heterogeneity of the tasks performed by different workers in the same occupations, Arntz et al. (2016) criticise the methodology of Frey and Osborne (2013). In order to account for the fact that not all workers in a given occupation have the same task profiles, they used data about individual tasks from the PIAAC survey (Programme for the International Assessment of Adult Competencies), thus also re-evaluating the automation potential in the United States. They used a German study by Bonin et al. (2015) as one of the sources of inspiration. In this study, the authors calculated that 12% of employees in Germany work in occupations at risk (using the approach of Frey and Osborne (2013), the share is 42%). The analysis by Bonin et al. (2015) also inspired the authors of an Austrian study by Nagl, Titelbach and Valková (2017), who calculated a share of 9% for Austria. While the approach of Frey and Osborne (2013) is called occupation-based, the approach based on the heterogeneity of jobs within the same occupations is called task-based. They estimate that in 21 OECD countries, only 9% of jobs on average are highly automatable. Workers face the lowest risk of automation in South Korea (6%) and the highest risk in Austria (12%). The share for Slovakia is 11%. At the same time, the study by Arntz et al. (2016) indicates that groups at the highest risk of automation include low-income population groups and workers with primary and lower secondary education. In this analysis, Slovakia's labour market is in the fourth place in

terms of risk, right after Austria, Germany and Spain. Based on the authors' main conclusion, it seems unlikely that tens of percent of jobs will be lost as a result of automation, which would lead to high technological unemployment. However, they point out the implications of automation for income inequalities and the growing importance of providing retraining for low-skilled workers.

A similar, but also somewhat modified approach is used by Nedelkoska and Quintini (2018), who extended their analysis to 32 OECD countries. In these countries, the average share of jobs at a high risk of automation is 14%. On country level, the shares range from 6 to 33%, while the country at the highest risk of automation is Slovakia. The average job in Slovakia is associated with a 57% automatability. In the case of EU countries, Pouliakas (2018) reached the same conclusion as Nedelkoska and Quintini (2018) that 14% of European workers between 24 and 65 years of age face a high risk of automation. While Arntz et al. (2016) and Nedelkoska and Quintini (2018) use almost identical data (PIAAC survey results) as well as methodology, Pouliakas (2018) uses the same methodology but opts for the results of the European skills and jobs (ESJ) survey. In contrast to Michlits et al. (2019), the results of this study suggest that automation can potentially lead to job loss for more men than women. At the same time, the potential negative impact of automation especially on low-skilled labour force is confirmed.

While authors of all the above-mentioned studies work with expert estimates that were used by Frey and Osborne (2013), Dengler and Matthes (2018) use their own expert estimates of the risk of automation faced by individual occupations in Germany. They note that they do not try to predict the future but focus on the current technological possibilities. Compared to the 47% in the case of using the occupation-based approach, the share using the task-based approach is significantly lower: 15% of German employment faces a high risk of automation. The results of their research also indicate that employment growth in individual occupations decreases with their automatability. A similar approach was chosen by Mihaylov and Tijdens (2019), who analyse the task content of the individual occupations in the International Standard Classification of Occupations (ISCO-08). They categorise these tasks into five groups – non-routine analytic, non-routine interactive, routine cognitive, routine manual and non-routine manual – and then estimate the share of employment at a high risk of automation in the Netherlands (11%).

Brynjolfsson et al. (2018) examined the potential of machine learning, a sub-area of artificial intelligence, to transform individual occupations and industries of the economy. They reached the conclusion that as opposed to the previous waves of automation, machine learning is unlikely to significantly impact only a certain part of the labour force; it will rather have a balanced impact across all occupations. They observe a very low correlation between the applicability of machine learning to tasks in individual occupations and the remuneration of those occupations. Therefore, a wider implementation of this technology should not be associated with growing income inequalities. The authors identify a significant variability in the applicability of machine learning to the tasks performed within almost all occupations, so the loss of a large number of jobs due to the implementation of this technology is highly unlikely. However, there will undoubtedly be changes in production processes and tasks will be reorganised.

Tichy (2016) notices significant differences in the estimated impacts of automation, and criticises the fact that authors usually focus on quantifying jobs that can be lost as a result of digitalisation and automation, but they fail to quantify jobs that the new technologies directly or indirectly create.

In his recent study on the impacts on the employment in Germany, he claims that new jobs will outnumber the lost jobs. For The Economist (2017), the respected Harvard professor Dani Rodrik said that he is sceptical about a massive loss of manufacturing jobs resulting from robotisation, especially in the developing world. Besides the high costs necessary for a full automation of certain tasks, the process is restricted especially by regulatory measures. Thus, it is likely that in many cases, some of the automatable activities will still be performed by humans.

As regards impacts on employment, there is another interesting fact: in the near future, automation could not only replace industrial tasks like it was the case until the present, but it will also gradually start applying to tasks in the services sector (e.g. banking, accounting or telemarketing). The international economics professor Richard Baldwin (2019) claims that this phenomenon could be happening *en masse*. Besides that, new jobs of a completely new nature should be created, which cannot be precisely defined today. Just like hardly anyone could anticipate the present-day number of people working in marketing or more luxurious services (personal trainers, masseurs, instructors, etc.) 30 years ago, we cannot exactly estimate the character of the new occupations. It is certain that there will be a boom in occupations which represent complements to the automated tasks, while jobs representing substitutes to industrial robots will disappear (Prettner et al., 2018).

## 2. Methodology and data

In this paper, the estimates of Frey and Osborne (2013), Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019) are applied to detailed Slovak employment data provided by TREXIMA Bratislava. At the country level, data on employment and average hourly wages for 401 4-digit SK ISCO-08 occupations for 2014 and 2019 are used. In addition to country-level data, TREXIMA Bratislava provided the corresponding data at the regional (SK-NUTS 4) and industry (2-digit SK NACE Rev. 2 codes) level. At the regional level, 79 districts can be distinguished.

Frey and Osborne (2013) provide their estimates of the probability of automation for 702 occupations in the Appendix of their paper. Similarly, Mihaylov and Tjidsens (2019) report the five task content measures (routine analytic, non-routine interactive, routine cognitive, routine manual and non-routine manual tasks) for 427 4-digit ISCO-08 occupations. In this case, the risk of automation is defined as the share of routine tasks. Dengler and Matthes (2018) do not provide their estimates of the substitutional potential for 384 4-digit ISCO-08 occupations directly in the paper. They had to be additionally requested from the authors.

The estimates of Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019) are easily applicable to the data used in this paper, as they use the same classification of occupations. In the case of Frey and Osborne (2013), a crosswalk between ISCO-08 and the 2010 SOC must be used. This crosswalk is provided by the Bureau of Labor Statistics<sup>4</sup>. Frey and Osborne (2013) distinguish between high-, medium- and low-risk occupations, depending on their probability of automation (thresholding at the probabilities of 0.7 and 0.3). The same categorisation is used by Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019). Therefore, this categorisation is used in this paper, too.

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<sup>4</sup> Available for download at: [https://www.bls.gov/soc/isco\\_soc\\_crosswalk.xls](https://www.bls.gov/soc/isco_soc_crosswalk.xls)

In the case of each of these approaches, it is possible to point out the advantages and disadvantages associated with their use. The advantage of working with the estimates of Frey and Osborne (2013) is the possibility of international comparison of the extent to which automation threatens the labour market of a particular country, as the same methodology has been applied by several other authors. The disadvantage is the process of translating their estimates of the probability of automation from the American to the international classification of occupations. Besides the technical complications and nuances connected to it, there is another problem, namely that Frey and Osborne's (2013) estimates are based on the tasks performed in individual occupations of the American classification of occupations, and thus are largely specific to the United States.

In the case of the estimates of Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019), this problem is not present. Dengler and Matthes (2018) provide their own expert estimates, which are based on the tasks performed within individual occupations in Germany, and as such should represent the automatability of occupations in Slovakia more accurately. Mihaylov and Tjidsens (2019) use the individual tasks performed within individual occupations of the international classification of occupations. Thus, similarly to Dengler and Matthes (2018), their estimates should capture the automatability of individual occupations in Slovakia in a more accurate manner. However, unlike in the case of Frey and Osborne (2013), an international comparison can be made in both cases with only one country – with Germany when using the estimates of Dengler and Matthes (2018) and with the Netherlands when using the estimates of Mihaylov and Tjidsens (2019). In addition, working with the estimates of Dengler and Matthes (2018) brings significant added value – the authors do not provide a forecast for the future, but rather assess current technological possibilities. The interpretation of the results will therefore differ accordingly.<sup>5</sup>

### **3. Empirical Results**

#### **3.1. Risk of automation for jobs in Slovakia**

Table 1 lists results obtained by using the approaches of FO, DM and MT. In two out of three cases, the values calculated for Slovakia are significantly higher than the authors' results for the countries they examined: 15% in Germany (DM) vs. 20% in Slovakia, and 11% in the Netherlands (MT) vs. roughly 22% in Slovakia. Using the estimates of FO, the calculated value is almost identical to the value that the authors obtained for the United States, but higher compared to values obtained by authors who replicated the FO methodology for Finland, Norway, Ireland or Austria (including Germany in the case of Bonin et al. (2015)). These shares represent employment at a high risk of automation, while a job at a high risk of automation can be defined as one consisting of at least 70% automatable tasks. Because this limit has been defined in an arbitrary manner, the average automatability of a job in the Slovak economy is also listed. Although the share of jobs at a high risk of automation using the DM approach is relatively low (around 40% of the value calculated using the FO estimates), the average job automatability at around 40% seems somewhat more significant in the relative comparison (69% of the value calculated using the FO estimates). This fact is a result of a relatively large share of jobs at a medium risk of automation (Figure 1). An interesting finding is that in terms of the occupational structure of employment, there was virtually

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<sup>5</sup> In the following section, FO will refer to Frey and Osborne (2013), DM to Dengler and Matthes (2018) and MT to Mihaylov and Tjidsens (2019).



no change between 2014 and 2019. Thus, it seems that the potential of new technologies to replace labour has not yet been materialised for various reasons (technical, economic or other). And even if it has materialised, workers replaced by technologies moved to other jobs with a similar average risk of automation.

Table 1: Share of employment at a high risk of automation and the average job automatability in Slovakia in 2014 and 2019

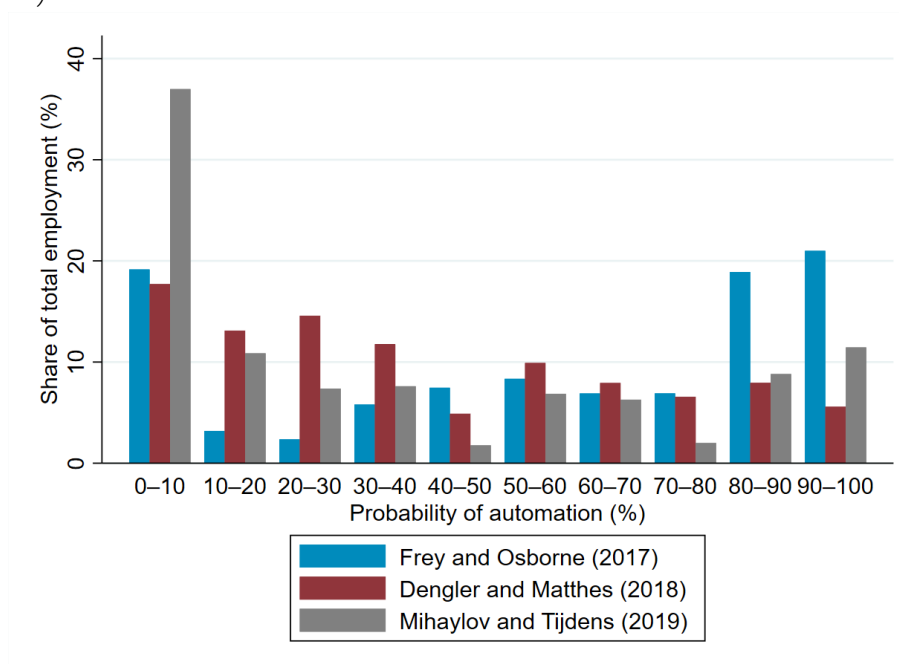
Approach	Share of employment at a high risk of automation (%)		Average job automatability (%)	
	2014	2019	2014	2019
Frey and Osborne (2013)	47.5	46.8	58.7	57.7
Dengler and Matthes (2018)	20.0	20.1	40.5	40.1
Mihaylov and Tijdens (2019)	22.6	22.3	36.0	35.1

Source: Authors' elaboration based on the estimates of Frey and Osborne (2013), Dengler and Matthes (2018) and Mihaylov and Tijdens (2019) and data from TREXIMA Bratislava.

Note: In the case of the average job automatability, the listed value is a weighted average.

Figure 1 demonstrates the distribution of employment in Slovakia by the risk of automation. An important finding is that when using the MT estimates, almost 40% of jobs in Slovakia fall within a category with only 0–10% automatable tasks. These jobs will not cease to exist as a result of the technological progress, and neither will they probably be associated with significant changes in the requirements for the competences, skills and education of workers and in the tasks performed as a part of these occupations. These jobs represent a considerable share of jobs on the total employment also when using FO and DM estimates: roughly a fifth of jobs will not cease to exist, nor will it be connected with significant changes.

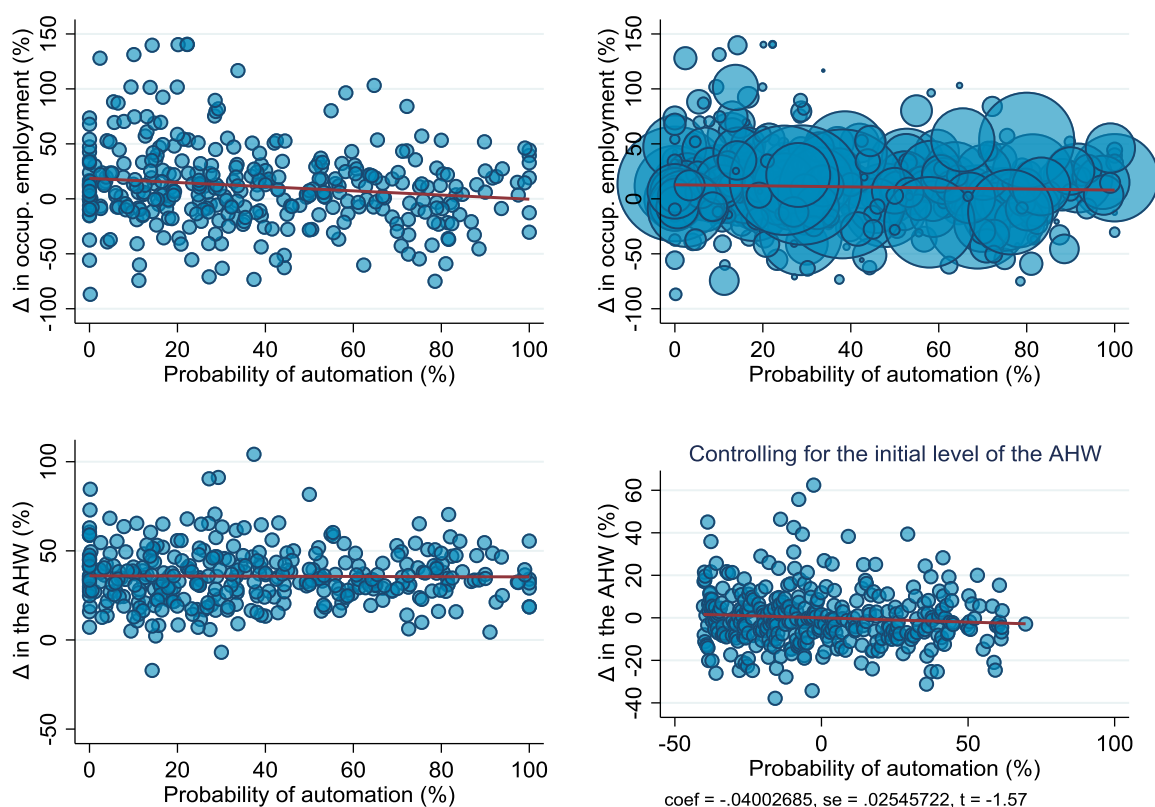
Figure 1: The distribution of occupational employment over the probability of automation in Slovakia (2019)



Source: Authors' elaboration based on the estimates of Frey and Osborne (2013), Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019) and data from TREXIMA Bratislava.

Furthermore, following the example of DM, the analysis in this paper also deals with the question whether on average, employment and wages increased (decreased) slower (faster) in the case of occupations at a higher risk of automation. The period of five years between 2014 and 2019 is examined, and this analysis only makes use of the DM estimates, as their definition makes it possible to expect the impact of technological progress on employment and wages already in 2013. Figure 2 indicates a weak negative relationship between the change in occupational employment and the probability of automation, with the calculated correlation coefficient of -0.14 (top left panel of Figure 2). However, this association almost disappears once the total occupational employment in 2014 is used as a weight (top right panel of Figure 2). It thus seems that substitutional potentials estimated by DM have already managed to exert their impact on the Slovak economy to a small extent in the form of employment changes.

Figure 2: Probability of automation and employment/average hourly wage (AHW) growth in Slovakia between 2014 and 2019



Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and data from TREXIMA Bratislava.

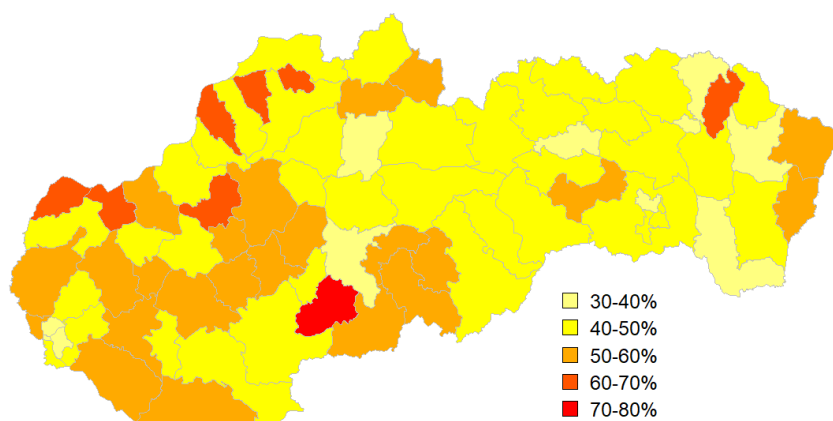
In contrast to the analysis of DM for Germany, the evidence for Slovakia is somewhat weak. Occupations with a high substitutional potential which experienced an employment decrease during the analysed period include typists and word processing operators (4131), metal polishers, wheel grinders and tool sharpeners (7244), manufacturing labourers not elsewhere classified (9329) and various machine operator jobs (petroleum and natural gas refining plant operators (3134), fibre

preparing, spinning and winding machine operators (8151), weaving and knitting machine operators (8152), textile, fur and leather products machine operators not elsewhere classified (8159) and food and related products machine operators (8160). However, looking at wages, no relationship between wage changes and automation probability has been identified (bottom panels of Figure 2).

### 3.2. Automation risk for jobs on the level of districts

When working with the FO estimates, districts with the largest shares of employment at a high risk of automation include Krupina (76%), Kysucké Nové Mesto (69%), Bytča (68%), Myjava (68%) and Bánovce nad Bebravou (63%), while districts with the lowest shares of employment at a high risk of automation are Svidník (31%), Levoča (33%), Ružomberok (35%), Bratislava III (35%) and Trebišov (37%) (Figure 3).

Figure 3: Share of employment at a high risk of automation by districts in 2019 (FO)



Source: Authors' elaboration based on the estimates of Frey and Osborne (2013) and data from TREXIMA Bratislava.

If we use the DM estimates, districts with the largest shares of employment at a high risk of automation include Kysucké Nové Mesto (63%), Bytča (50%), Skalica (46%), Myjava (43%) and Bánovce nad Bebravou (43%), and districts with the lowest shares of employment at a high risk of automation include Gelnica (5%), Svidník (6%), Košice I (6%), Bratislava V (6%) and Bratislava I (7%) (Appendix 1).

The results when using the MT estimates are similar. Districts with the largest shares of employment at a high risk of automation are Kysucké Nové Mesto (56%), Bytča (45%), Myjava (41%), Nové Mesto nad Váhom (41%) and Žarnovica (40%), and districts with the lowest shares of employment at a high risk of automation include Levoča (4%), Gelnica (6%), Svidník (8%), Ružomberok (10%) and Snina (11%) (Appendix 2).

Averaging the values calculated using the individual approaches, the results are the following: Kysucké Nové Mesto, Bytča, Myjava, Skalica and Krupina are districts with the largest shares of employment at a high risk of automation, and Svidník, Levoča, Ružomberok, Košice I and

Trebišov are districts with the lowest shares of employment at a high risk of automation. In this regard, an important finding is that the technological progress, it seems, does not have a potential to increase the existing regional differences in Slovakia, or have a greater impact on districts that already face a high unemployment rate today. A common characteristic of the districts at the highest risk of automation is an average or a below-average unemployment rate. In 2019, the registered unemployment rate in these districts ranged from 2.9 (Myjava) to 5.3% (Bytča), while the nationwide figure was 4.9%. In contrast, districts at the lowest risk of automation include three with an above-average unemployment rate – Trebišov (11.02%), Svidník (10.78%) and Levoča (7.99%). Trebišov and Svidník had the seventh and eighth highest registered unemployment rate in 2019. Using the MT estimates, the districts also include Gelnica (8.66%) or Snina (7.48%).<sup>6</sup>

### 3.3. Automation poses a risk mainly for low-income employee groups

Besides information on the number of employees, the data from TREXIMA Bratislava also includes average hourly wages on the level of the 4-digit SK ISCO-08 occupations. The analysis of the relation between the automatability of a job and the wage level provides interesting findings and implications.

The calculated results indicate a negative relationship between the automatability of a job and the wage level – on average, automation risk of an occupation decreases with an increase in the average hourly wage. Employees with lower incomes face a higher risk of losing their job as a result of the technological progress. The specific values when working with the FO estimates are the following: the average hourly wage of employees at a low, medium and high risk of automation in 2019 reached around EUR 10, EUR 7 and EUR 6.50, respectively. The exact values and the results for the estimates of DM and MT can be found in Table 2. Thus, our results are in line with the results of Arntz et al. (2016) or Pouliakas (2018).

Table 2: Average hourly wages (AHW) of employees at a low, medium or high risk of automation in 2019

Approach	AHW of employees at a low risk of automation (EUR)	AHW of employees at a medium risk of automation (EUR)	AHW of employees at a high risk of automation (EUR)
Frey and Osborne (2013)	10.14	7.14	6.46
Dengler and Matthes (2018)	8.26	7.34	6.97
Mihaylov and Tjzens (2019)	8.58	6.36	6.78

Source: Authors' elaboration based on the estimates of Frey and Osborne (2013), Dengler and Matthes (2018) and Mihaylov and Tjzens (2019) and data from TREXIMA Bratislava.

Note: The values are weighted averages.

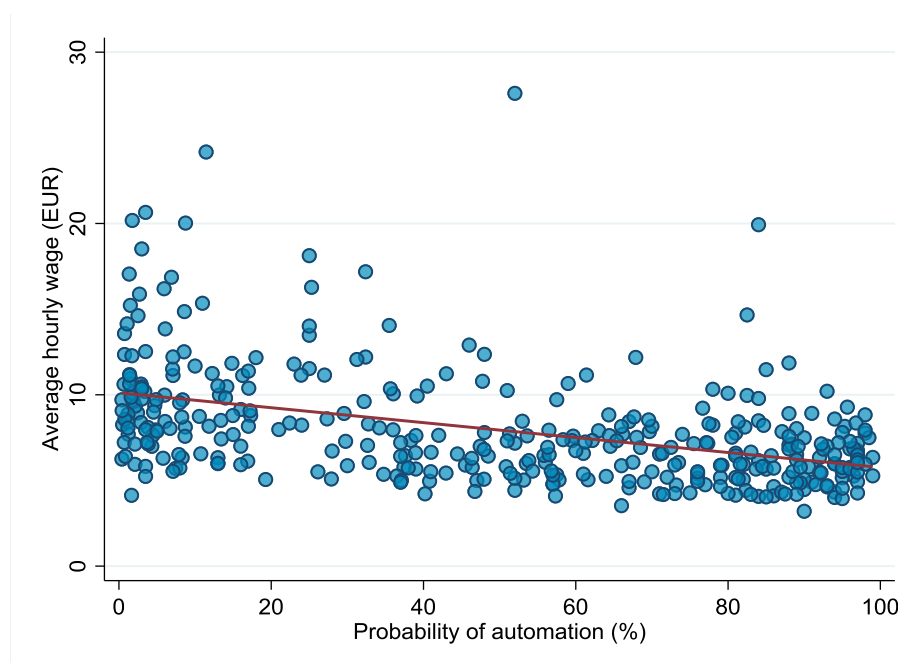
Figure 4 indicates a strong negative relationship between the average hourly wage and the probability of automation, with the calculated correlation coefficient of -0.43.<sup>7</sup> Because significant wage differences can be identified among the occupations at a low risk of automation, the progressing automation is also connected to a risk of increasing income inequality – technological

<sup>6</sup> Source of the data about the registered unemployment rate is the DATAcube. database of the Statistical Office of the Slovak Republic (<http://datacube.statistics.sk/>).

<sup>7</sup> However, Appendix 3 shows that this relationship is significantly weaker for the DM and MT estimates.

progress threatens mainly low- and medium-skilled labour force (e.g. Hawksworth et al., 2018), and the potential increase of low- and medium-skilled labour supply under the conditions of a limited number of (still) not automated/non-automatable jobs suitable for this population group will exert pressure on the wages in these positions and decrease them (even further).

Figure 4: Average hourly wage in 2019 vs. automation probability of an occupation (FO)



Source: Authors' elaboration based on the estimates of Frey and Osborne (2013) and data from TREXIMA Bratislava.

### 3.4. Employment in Slovakia at a risk of automation by industries and occupations

This section identifies those industries in Slovakia which have the strongest representation of occupations at a high risk, whether it be percentagewise or in absolute terms, again using the estimates of automation probabilities for individual occupations according to FO, DM and MT<sup>8</sup>.

#### 3.4.1 Industries and occupations at risk using the probabilities by Frey and Osborne (2013)

First, industries at risk were examined using the automation probabilities for individual occupations calculated by FO. Table 3 lists industries in Slovakia ordered by the share and then the absolute number of workers in occupations at a high risk of automation. Industries most at risk in terms of the *percentage* include some services which can be categorised under market services, but also several manufacturing industries. The top 10 among market services includes security and investigation activities, food and beverage service activities, and the printing and reproduction of recorded media. As regard manufacturing, there are industries like the manufacture of rubber and plastic products, the manufacture of wearing apparel, the manufacture of furniture, the manufacture of wood and the manufacture of food products.

<sup>8</sup> Based on the studies of authors dealing with the potential impacts of automation (FO, DM and MT), occupations at a high risk are defined as those with the risk of automation estimated at 70% or more. The probability of automation below 30% is considered low and the interval of 30 to 70% is considered medium.

Most people employed in the security and investigation activities industry work in the position of security guards, reaching as many as 90%. In food and beverage service activities, occupations that should be mentioned include mainly waiters, cooks (except chefs) and kitchen helpers. In manufacturing industries, the highest risk is faced by plant and machine operatives and assemblers (Table 4).

Table 3: Top 10 industries in Slovakia in terms of the share and absolute number of workers in occupations at a high risk of automation (over 70%) according to Frey and Osborne, 2019

Industry name (SK NACE)	Jobs at risk	Share on the total employment of the industry
<b>Ordered by the share</b>		
80 Security and investigation activities	32,422	95.6%
56 Food and beverage service activities	38,029	84.1%
18 Printing and reproduction of recorded media	3,501	79.4%
69 Legal and accounting services	23,235	77.4%
22 Manufacture of rubber and plastic products	38,392	75.9%
14 Manufacture of wearing apparel	12,160	75.6%
31 Manufacture of furniture	15,454	73.6%
28 Manufacture of machinery and equipment n.e.c.	49,560	72.5%
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	13,851	72.0%
10 Manufacture of food products	33,768	70.1%
<b>Ordered by the absolute number</b>		
47 Retail trade, except of motor vehicles and motorcycles	129,538	68.6%
29 Manufacture of motor vehicles, trailers and semi-trailers	77,178	68.9%
46 Wholesale trade, except of motor vehicles and motorcycles	69,967	48.3%
84 Public administration and defence; compulsory social security	68,901	40.9%
25 Manufacture of fabricated metal products, except machinery and equipment	49,824	69.3%
28 Manufacture of machinery and equipment n.e.c.	49,560	72.5%
01 Crop and animal production, hunting and related service activities	41,342	67.7%
85 Education	38,955	15.6%
22 Manufacture of rubber and plastic products	38,392	75.9%
56 Food and beverage service activities	38,029	84.1%

Source: Authors' elaboration based on the estimates of Frey and Osborne (2013) and data from TREXIMA Bratislava.

However, in terms of employment, it is interesting to know which industries are at risk in terms of the *number* of workers in occupations at risk. In Slovakia in 2019, the largest number worked in retail trade, automotive industry and wholesale trade. Despite the fact that there are industries with a higher risk in terms of percentage, the highest potential loss in terms of the number of jobs can be expected in these industries, reaching almost 130 thousand in retail trade, 77 thousand in automotive industry and almost 70 thousand in wholesale trade. The manufacture of machinery and equipment, the manufacture of rubber and plastic products and food and beverage service activities can be found in the top 10 of this ranking, too. Thus, they are in the group facing the highest risk not only in terms of percentage but also in terms of the number of jobs in occupations at risk. Moreover, this list also includes public administration and defence (68,901 jobs), the manufacture of fabricated metal products (49,824 jobs) and crop and animal production, with over 41 thousand people in occupations at a higher risk in Slovakia in 2019.

Table 4: 4-digit ISCO occupations with the highest representation in the top 5 industries at the highest risk in Slovakia by share, Frey and Osborne, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>80 Security and investigation activities</b>			
<b>5414</b>	Security guards	30,821	90.9%
<b>5411</b>	Firefighters	708	2.1%
<b>4110</b>	General office clerks	553	1.6%
<b>56 Food and beverage service activities</b>			
<b>5131</b>	Waiters and sommeliers	10,563	23.4%
<b>5120</b>	Cooks (except chefs)	9,623	21.3%
<b>9412</b>	Kitchen helpers	7,067	15.6%
<b>18 Printing and reproduction of recorded media</b>			
<b>7323</b>	Print finishing and binding workers	1,365	30.9%
<b>9329</b>	Manufacturing labourers not elsewhere classified	642	14.6%
<b>7322</b>	Printers	632	14.3%
<b>69 Legal and accounting services</b>			
<b>3313</b>	Accounting associate professionals	9,558	31.8%
<b>2411</b>	Accountants	9,202	30.7%
<b>4311</b>	Accounting and bookkeeping clerks	1,940	6.5%
<b>22 Manufacture of rubber and plastic products</b>			
<b>8142</b>	Plastic products machine operators	12,944	25.6%
<b>8141</b>	Rubber products machine operators	8,629	17.1%
<b>8219</b>	Assemblers not elsewhere classified	3,350	6.6%

Source: Authors' elaboration based on the estimates of Frey and Osborne (2013) and data from TREXIMA Bratislava.

Using the following table (Table 5), it is possible to see the most represented occupations in the industries at risk. In retail trade, more than a third of workers work as shop sales assistants, and further 13% and 10% as cashiers and shop supervisors, respectively. In the industry with the second highest risk in absolute terms, i.e. the manufacture of motor vehicles, trailers and semi-trailers, the relevant occupations include mechanical machinery assemblers, electrical and electronic equipment assemblers and assemblers not elsewhere classified, together accounting for almost half of the total employment in the industry. From this perspective, employment in the automotive industry in Slovakia can be considered as facing a high risk. Other occupations at risk include commercial sales representatives, stock clerks and shop sales assistants in wholesale trade, as well as government regulatory associate professionals, and, in the manufacture of fabricated metal products, metal working machine tool setters and operators, operatives, locksmiths and toolmakers.

Using a reversed perspective, the lowest representation of occupations at risk in terms of percentage, but usually also in absolute terms, can be found in industries such as creative, arts and entertainment activities (22%), scientific research and development (20%), information service activities (13%), human health activities (13%), computer programming and consultancy activities (13%), motion picture, video and television programme production (10%) and programming and broadcasting activities (3%)<sup>9</sup>.

<sup>9</sup> Authors will gladly provide the complete list of industries ordered by the share and the absolute numbers upon request.

Table 5: 4-digit ISCO occupations with the largest representation in the top 5 occupations at the highest risk in Slovakia in terms of the absolute number of persons employed, Frey and Osborne, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>47 Retail trade, except of motor vehicles and motorcycles</b>			
5223	Shop sales assistants	69,174	36.6%
5230	Cashiers and ticket clerks	24,214	12.8%
5222	Shop supervisors	17,619	9.3%
<b>29 Manufacture of motor vehicles, trailers and semi-trailers</b>			
8211	Mechanical machinery assemblers	36,242	32.4%
8212	Electrical and electronic equipment assemblers	7,337	6.5%
8219	Assemblers not elsewhere classified	6,992	6.2%
<b>46 Wholesale trade, except of motor vehicles and motorcycles</b>			
3322	Commercial sales representatives	18,001	12.4%
4321	Stock clerks	17,342	12.0%
5223	Shop sales assistants	11,222	7.7%
<b>84 Public administration and defence; compulsory social security</b>			
3359	Government regulatory associate professionals not elsewhere classified	12,964	7.69%
3353	Government social benefits officials	8,347	4.95%
5322	Home-based personal care workers	7,737	4.59%
<b>25 Manufacture of fabricated metal products, except machinery and equipment</b>			
7223	Metal working machine tool setters and operators	9,946	13.83%
8211	Mechanical machinery assemblers	7,394	10.28%
7222	Toolmakers and related workers	6,162	8.57%

Source: Authors' elaboration based on the estimates of Frey and Osborne (2013) and data from TREXIMA Bratislava.

### 3.4.2 Industries and occupations at risk using the probabilities by Dengler and Matthes (2018)

There is a significantly lower number of occupations deemed to be at risk according to DM compared to the estimates of FO. In specific terms, this applies to 20% of the total employment in Slovakia in 2019, which represents just below 500 thousand jobs. Another difference compared to the previous results lies in the representation of industries. Top 10 industries in terms of the share of workers in occupations at a high risk of automation only include manufacturing industries. The following table (Table 6) demonstrates that the largest share of occupations at risk in the total employment of an industry can be found in the manufacture of basic metals, the manufacture of wood, and the manufacture of machinery and equipment. The share exceeds 60% also in the case of the printing and reproduction of recorded media, the manufacture of fabricated metal products and the manufacture of paper and paper products. In the automotive industry, the share of employment in occupations at risk reaches 56.5%, which, in absolute terms, is more than 63 thousand jobs. Thus, the manufacture of motor vehicles faces the highest risk in terms of the number of workers. A similar risk is faced by the manufacture of machinery and equipment, the manufacture of fabricated metal products, with more than 43 thousand workers each, representing roughly 60% of the employment in these industries. As regards market services, the relevant industries include, similarly to FO, retail trade, but also employment activities.



Table 6: Top 10 industries in Slovakia in terms of the share and absolute number of workers in occupations at a high risk of automation (over 70%) according to Dengler and Matthes, 2019

Industry name (SK NACE)	Jobs at risk	Share on the total employment of the industry
<b>Ordered by the share</b>		
24 Manufacture of basic metals	20,048	67.8%
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	13,037	67.8%
28 Manufacture of machinery and equipment n.e.c.	43,832	64.1%
18 Printing and reproduction of recorded media	2,781	63.0%
25 Manufacture of fabricated metal products, except machinery and equipment	43,574	60.6%
17 Manufacture of paper and paper products	5,968	60.2%
30 Manufacture of other transport equipment	2,886	58.6%
29 Manufacture of motor vehicles, trailers and semi-trailers	63,344	56.5%
32 Other manufacturing	5,418	55.7%
15 Manufacture of leather and related products	6,204	55.7%
<b>Ordered by the absolute number</b>		
29 Manufacture of motor vehicles, trailers and semi-trailers	63,344	56.5%
28 Manufacture of machinery and equipment n.e.c.	43,832	64.1%
25 Manufacture of fabricated metal products, except machinery and equipment	43,574	60.6%
47 Retail trade, except of motor vehicles and motorcycles	32,306	17.1%
22 Manufacture of rubber and plastic products	24,919	49.3%
24 Manufacture of basic metals	20,048	67.8%
10 Manufacture of food products	19,131	39.7%
78 Employment activities	18,857	54.8%
27 Manufacture of electrical equipment	16,402	31.9%
01 Crop and animal production, hunting and related service activities	15,147	24.8%

Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and data from TREXIMA Bratislava.

Looking at specific 4-digit ISCO occupations (Table 7 and Table 8), it is clear that percentage-wise, the industries at risk have the largest representation of locksmiths, toolmakers and related workers, manufacturing labourers not elsewhere classified, plant operatives, and metal working machine tool setters and operators. In some manufacturing industries, the occupation at the highest risk accounts for as much as around 30% of the total employment in the industry, which further increases the probability that a substantial number of jobs will be replaced in these sectors in the future.

Table 7: 4-digit ISCO occupations with the highest representation in the top 5 industries at the highest risk in Slovakia by share, Dengler and Matthes, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>24 Manufacture of basic metals</b>			
8121	Metal processing plant operators	8,502	28.8%
7222	Toolmakers and related workers	2,774	9.4%
7223	Metal working machine tool setters and operators	1,544	5.2%
<b>16 Manufacture of wood and of products of wood and cork, except furniture</b>			
9329	Manufacturing labourers not elsewhere classified	4,990	26.0%
8172	Wood processing plant operators	4,396	22.9%
7521	Wood treaters	2,141	11.1%
<b>28 Manufacture of machinery and equipment n.e.c.</b>			

7223	Metal working machine tool setters and operators	18,557	27.1%
8211	Mechanical machinery assemblers	9,066	13.3%
7222	Toolmakers and related workers	4,212	6.2%
<b>18 Printing and reproduction of recorded media</b>			
7323	Print finishing and binding workers	1,365	30.9%
9329	Manufacturing labourers not elsewhere classified	642	14.6%
7322	Printers	632	14.3%
<b>25 Manufacture of fabricated metal products, except machinery and equipment</b>			
7223	Metal working machine tool setters and operators	9,946	13.8%
8211	Mechanical machinery assemblers	7,394	10.3%
7222	Toolmakers and related workers	6,162	8.6%

Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and data from TREXIMA Bratislava.

The automotive industry is very significant for Slovakia. For that reason, the representation of occupations in the manufacture of motor vehicles, trailers and semi-trailers will be examined in more detail (Table 8). The highest risk is mainly faced by workers in occupations classified as group 7 – craft and related trades workers, and group 8 – plant and machine operators, and assemblers. Almost a third of persons employed in this industry work in the position of mechanical machinery assemblers. Next, roughly 6% work as electrical and electronic equipment assemblers and further 6% as assemblers not elsewhere classified. A similar structure of group 7 and 8 occupations can also be found in the remaining manufacturing industries.

Table 8: 4-digit ISCO occupations with the largest representation in the top 5 occupations at the highest risk in Slovakia in terms of the absolute number of persons employed, Dengler and Matthes, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>29 Manufacture of motor vehicles, trailers and semi-trailers</b>			
8211	Mechanical machinery assemblers	36,242	32.4%
8212	Electrical and electronic equipment assemblers	7,337	6.5%
8219	Assemblers not elsewhere classified	6,992	6.2%
<b>28 Manufacture of machinery and equipment n.e.c.</b>			
7223	Metal working machine tool setters and operators	18,557	27.1%
8211	Mechanical machinery assemblers	9,066	13.3%
7222	Toolmakers and related workers	4,212	6.2%
<b>25 Manufacture of fabricated metal products, except machinery and equipment</b>			
7223	Metal working machine tool setters and operators	9,946	13.8%
8211	Mechanical machinery assemblers	7,394	10.3%
7222	Toolmakers and related workers	6,162	8.6%
<b>47 Retail trade, except of motor vehicles and motorcycles</b>			
5223	Shop sales assistants	69,174	36.6%
5230	Cashiers and ticket clerks	24,214	12.8%
5222	Shop supervisors	17,619	9.3%
<b>22 Manufacture of rubber and plastic products</b>			
8142	Plastic products machine operators	12,944	25.6%
8141	Rubber products machine operators	8,629	17.1%
8219	Assemblers not elsewhere classified	3,350	6.6%

Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and data from TREXIMA Bratislava.

In contrast, industries with the lowest risk include social work activities, residential care activities, financial service activities except insurance, as well as insurance, reinsurance and pension funding, with occupations at risk accounting for less than 1.5%<sup>10</sup>. However, the list includes many industries with automation risk below 10%.

### 3.4.3 Industries and occupations at risk using the probabilities by Mihaylov and Tijdens (2019)

Finally, estimates of occupation automatability by MT will be used as well. In terms of the share of occupations at risk on the total employment of a given industry, the first place belongs to gambling and betting activities (87.2%). However, in 2019 in Slovakia, the absolute number of workers in this industry was less than 10 thousand. In terms of occupations, these include especially bookmakers, croupiers and related gaming workers, accounting for 83% of the industry's total employment (Table 10). Furthermore, it can be observed (Table 9) that as regards services, postal and courier activities (61.6 %) are represented as well, again with roughly 10 thousand workers in occupations at risk. In this case, more than 50% of persons employed work as mail carriers and sorting clerks, and 18% as supply, distribution and related managers (Table 10). The remaining industries include parts of manufacturing, while the manufacture of rubber and plastic products (63.6 %) and the manufacture of motor vehicles, trailers and semi-trailers (60.5 %) rank the highest.

Table 9: Top 10 industries in Slovakia in terms of the share and absolute number of workers in occupations at a high risk of automation (over 70%) according to Mihaylov and Tijdens, 2019

Industry name (SK NACE)	Jobs at risk	Share on the total employment of the industry
<b>Ordered by the share</b>		
92 Gambling and betting activities	9,373	87.2%
22 Manufacture of rubber and plastic products	32,181	63.6%
53 Postal and courier activities	10,063	61.6%
29 Manufacture of motor vehicles, trailers and semi-trailers	67,749	60.5%
18 Printing and reproduction of recorded media	2,629	59.6%
28 Manufacture of machinery and equipment n.e.c.	38,026	55.6%
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	1,386	55.6%
17 Manufacture of paper and paper products	5,048	50.9%
27 Manufacture of electrical equipment	25,776	50.1%
26 Manufacture of computer, electronic and optical products	11,121	49.7%
<b>Ordered by the absolute number</b>		
29 Manufacture of motor vehicles, trailers and semi-trailers	67,749	60.5%
47 Retail trade, except of motor vehicles and motorcycles	41,040	21.7%
46 Wholesale trade, except of motor vehicles and motorcycles	38,348	26.4%
28 Manufacture of machinery and equipment n.e.c.	38,026	55.6%
25 Manufacture of fabricated metal products, except machinery and equipment	34,229	47.6%
22 Manufacture of rubber and plastic products	32,181	63.6%
27 Manufacture of electrical equipment	25,776	50.1%
84 Public administration and defence; compulsory social security	21,287	12.6%
10 Manufacture of food products	14,347	29.8%
24 Manufacture of basic metals	13,377	45.3%

Source: Authors' elaboration based on the estimates of Mihaylov and Tijdens (2019) and data from TREXIMA Bratislava.

<sup>10</sup> Authors will gladly provide the complete list of industries ordered by the share and the absolute numbers upon request.

In terms of the number of jobs at risk, the first place, and with a significant difference compared to other industries, belongs to the automotive industry, with more than 67 thousand workers in 2019 in Slovakia working in occupations at risk according to the estimates of MT. Similarly to the estimates by FO and DM, the most represented occupations belong to group 8, and these are also at the highest risk in terms of their future automatability. They include mechanical machinery assemblers, electrical and electronic equipment assemblers, and assemblers not elsewhere classified (Table 11). In retail and wholesale trade, the occupations concerned again include shop sales assistants, cashiers and stock clerks. In the manufacture of machinery and equipment, the same structure of occupations can be observed as in the case of the previous estimates, i.e. mainly including plant operatives, tool settlers, locksmiths and toolmakers.

Table 10: 4-digit ISCO occupations with the highest representation in the top 5 industries at the highest risk in Slovakia by share, Mihaylov and Tjijdens, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>92 Gambling and betting activities</b>			
4212	Bookmakers, croupiers and related gaming workers	8,934	83.1%
3115	Mechanical engineering technicians	620	5.8%
3513	Computer network and systems technicians	241	2.2%
<b>22 Manufacture of rubber and plastic products</b>			
8142	Plastic products machine operators	12,944	25.6%
8141	Rubber products machine operators	8,629	17.1%
8219	Assemblers not elsewhere classified	3,350	6.6%
<b>53 Postal and courier activities</b>			
4412	Mail carriers and sorting clerks	8,906	54.5%
1324	Supply, distribution and related managers	2,997	18.3%
3119	Physical and engineering science technicians not elsewhere classified	1,118	6.8%
<b>29 Manufacture of motor vehicles, trailers and semi-trailers</b>			
8211	Electrical and electronic equipment assemblers	36,242	32.4%
8212	Electrical and electronic equipment assemblers	7,337	6.5%
8219	Assemblers not elsewhere classified	6,992	6.2%
<b>18 Printing and reproduction of recorded media</b>			
7323	Print finishing and binding workers	1,365	30.9%
9329	Manufacturing labourers not elsewhere classified	642	14.6%
7322	Printers	632	14.3%

Source: Authors' elaboration based on the estimates of Mihaylov and Tjijdens (2019) and data from TREXIMA Bratislava

Industries at the lowest risk of automation using MT estimates include social work activities, where 1.8% of the industry's total employment is at risk and only 120 people work in occupations at risk. This is followed by security and investigation activities with 2.5% and 845 jobs, and residential care activities with 2.8% and 819 jobs. Activities under 5% also include services to buildings and landscape activities (3.8% of the industry's total employment is at risk, representing 765 jobs) and human health activities (4.9% and 7,132 jobs at risk).

Table 11: 4-digit ISCO occupations with the largest representation in the top 5 occupations at the highest risk in Slovakia in terms of the absolute number of persons employed, Mihaylov and Tjidsens, 2019

ISCO	Occupation title	Number of workers in the occupation	Share on the total employment of the industry
<b>29 Manufacture of motor vehicles, trailers and semi-trailers</b>			
8211	Mechanical machinery assemblers	36,242	32.4%
8212	Electrical and electronic equipment assemblers	7,337	6.5%
8219	Assemblers not elsewhere classified	6,992	6.2%
<b>47 Retail trade, except of motor vehicles and motorcycles</b>			
5223	Shop sales assistants	69,174	36.6%
5230	Cashiers and ticket clerks	24,214	12.8%
5222	Shop supervisors	17,619	9.3%
<b>46 Wholesale trade, except of motor vehicles and motorcycles</b>			
3322	Commercial sales representatives	18,001	12.4%
4321	Stock clerks	17,342	12.0%
5223	Shop sales assistants	11,222	7.7%
<b>28 Manufacture of machinery and equipment n.e.c.</b>			
7223	Metal working machine tool setters and operators	18,557	27.1%
8211	Mechanical machinery assemblers	9,066	13.3%
7222	Toolmakers and related workers	4,212	6.2%
<b>25 Manufacture of fabricated metal products, except machinery and equipment</b>			
7223	Metal working machine tool setters and operators	9,946	13.8%
8211	Mechanical machinery assemblers	7,394	10.3%
7222	Toolmakers and related workers	6,162	8.6%

Source: Authors' elaboration based on the estimates of Mihaylov and Tjidsens (2019) and data from TREXIMA Bratislava

## Conclusions

The aim of this paper was to examine the possible impacts of technological progress in the form of automation and digitalisation on the labour market and the nature of work in Slovakia. Besides quantifying the share of Slovak employment at a high risk of automation, the risk of labour automation was analysed in detail in terms of regional, industry and occupational aspects. To do so, detailed data on employment and wages, as well as automatability estimates (or substitutional potentials) for individual occupations according to Frey and Osborne (2013), Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019) were used.

Automation risk values for Slovakia are much higher than in countries in the original studies by Dengler and Matthes (2018) and Mihaylov and Tjidsens (2019) (Germany and the Netherlands), and somewhat higher than the values calculated using the methodology of Frey and Osborne (2013) for Austria, Germany or Ireland (when compared to Finland and Norway, the differences are significant). These results are in line with previous international studies, according to which Slovakia faces one of the highest risks. In 2019, depending on the approach taken, the share of employment in Slovakia at a high risk of automation ranged from about 20 to 47%. Other findings show that employees with a lower income face a higher risk of losing their job as a result of technological progress. Using the estimates of Frey and Osborne (2013), we found that the average hourly wage of employees at a low, medium and high risk of automation in 2019 reached around EUR 10, EUR 7 and EUR 6.50, respectively.

Automation risk for jobs in the Slovak economy has been estimated also on the level of individual districts and industries. Districts at the highest risk of automation include Kysucké Nové Mesto, Bytča, Myjava, Skalica and Krupina, while districts with the lowest share of employment at risk are Svidník, Levoča, Ružomberok, Košice I and Trebišov. A key finding is that technological progress is not likely to increase the existing regional differences in terms of employment opportunities in Slovakia. A common characteristic of the districts at the highest risk of automation is an average or a below-average unemployment rate. In contrast, two of five districts at the lowest risk of automation ranked seventh and eighth in terms of registered unemployment rate in 2019.

Industries with the largest share of employment at a very high risk include many manufacturing industries, as well as wholesale and retail trade. Other service industries can be included here as well, but their significance for the national economy in terms of the number of workers is rather low. Service industries with a low number of employees but a high rate of automation risk include, for instance, the printing and reproduction of recorded media, gambling and betting activities, legal and accounting services, security and investigation activities, as well as food and beverage service activities. In services, a significant proportion of employment is at risk in retail and wholesale trade, mainly including shop sales assistants, cashiers, ticket clerks, commercial sales representatives and stock clerks. In manufacturing, this includes the manufacture of motor vehicles, trailers and semi-trailers, which has a large share of employees at a high risk of automation. These work especially in occupations like mechanical machinery assemblers and electrical equipment assemblers. Other industries that can be mentioned are the manufacture of machinery and equipment, the manufacture of fabricated metal products, and the manufacture of basic metals.

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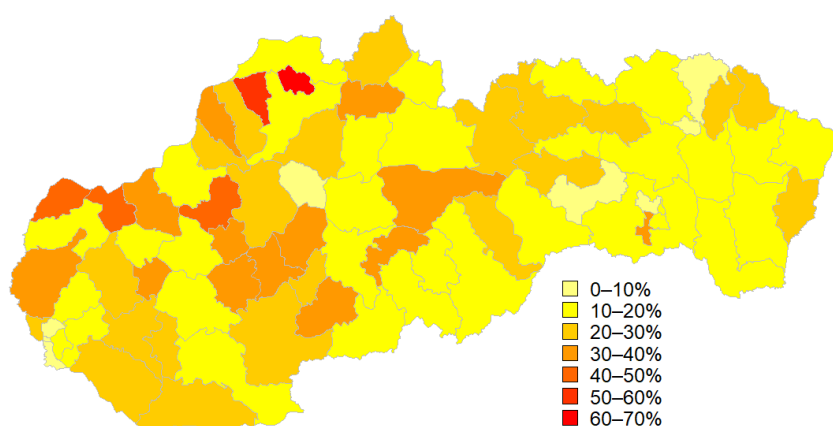
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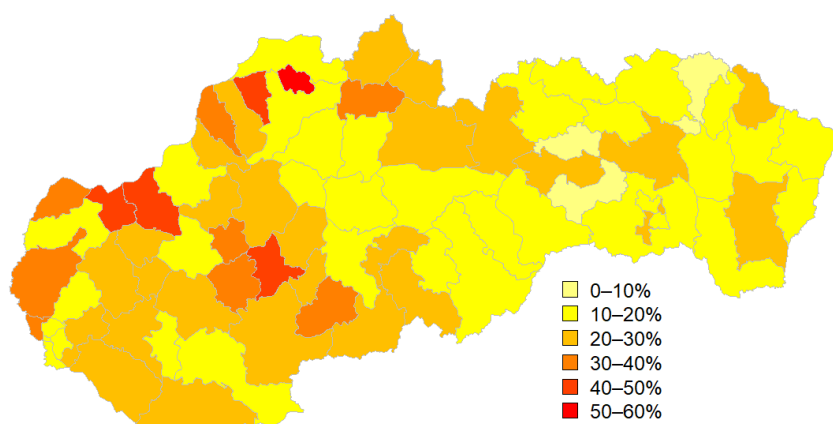
## Appendix

Appendix 1: Share of employment at a high risk of automation by districts in 2019 (DM)



Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and data from TREXIMA Bratislava.

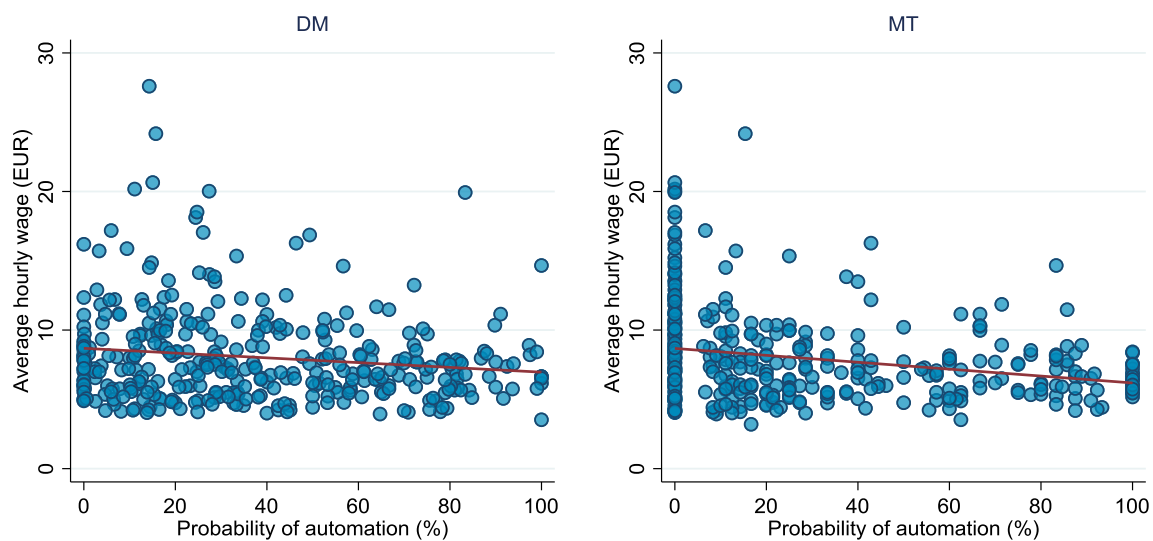
Appendix 2: Share of employment at a high risk of automation by districts in 2019 (MT)



Source: Authors' elaboration based on the estimates of Mihaylov and Tijdens (2019) and data from TREXIMA Bratislava.



Appendix 3: Average hourly wage in 2019 vs. automation probability of an occupation (DM and MT)



Source: Authors' elaboration based on the estimates of Dengler and Matthes (2018) and Mihaylov and Tijdens (2019) and data from TREXIMA Bratislava.