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ORIGINAL PAPER

Industry 4.0–the future of Austrian jobs

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Abstract

What are the socio-economic effects of the widespread introduction of robots, algorithms and digital technologies like artificial intelligence and machine learning? Following Frey and Osborne (London futures agiletown : the relentless march of technology and London's response. Deloitte, 2014, Technol Forecast Social Change 114(C), 254–280, 2017, https://doi.org/10.1016/j.techfore.2016.08.019) we apply the computerization probabilities to occupations in Austria. We conclude that about 40% of the Austrian workforce is active in occupations that are very likely to undergo substantial changes regarding task structure, skill requirement and working environment in the future, causing challenges and opportunities. We also provide evidence that compared to men, women in Austria seem more likely to be affected by technological changes, with sectoral orientation playing a role. Following EBRD (Skills, employment and automation. Chapter 2 in: EBRD (2018): Transition Report 2018–19, European Bank for Reconstruction and Development, London, 2018),we see a broader move towards job polarization. We see this as distributive consequences of technological change and argue that the consequences of technology refashioning socio-economic development are influencing market processes, actors and inequalities. As in previous technological advances, coping with these changes will require efforts on the individual as well as on the political level.

Keywords Computerization · Technological change · Labor demand · Skill demand

JEL Classification J21 · J23 · J24 · J62 · O33

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1 Introduction

The aim of this study is to examine how digitization and technological advances will affect the Austrian labor market. Currently, discussions about future Industry 4.0 scenarios seem to be omnipresent. But what does the term “Industry 4.0” actually mean? The European parliament describes it as “a term applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products” (Davis 2015, p. 2). Schwarzbauer (2017) emphasizes the holistic changes in value chains across the production cycle and across stakeholders, including platform economics and digital market places. According to Davis (2015), “4.0” signifies that this technological process represents the fourth industrial revolution. Like the previous 3 revolutions, Industry 4.0 is expected to have a significant impact on productivity and is also meant to change the human way of living. This raises questions on how a potential automation of tasks caused by new technologies will impact the human workforce. Following a landmark study by Frey and Osborne (2017)[1] concerning the computerization of US occupations, we try to answer this question for jobs in Austria.

Frey and Osborne (2017) estimate that a share of 47% of all workers in the US is exposed to a high risk of computerization in the future. Some other studies followed, which used their computerization probabilities to examine the automation risk of jobs in other countries. Generally, we distinguish between two different approaches of previous studies on this subject. First, following Arntz et al. (2016), we refer to the occupation-based approach as a translation of the results obtained by Frey and Osborne (2017) into occupations in other countries (e.g. Brzeski and Burk 2015; Pajarinen et al. 2015). This approach is generally recommended and used by Frey and Osborne (2014, 2017) themselves to translate their results (the authors used this approach to examine job automation in the UK). Secondly, we refer to the task-based approach as methodology which uses the relationship of Frey and Osborne’s (2017) computerization probabilities and the underlying task profiles of jobs in order to examine the computerization risk of jobs in other countries while focusing on the automation of tasks (e.g. Bonin et al. 2015; Dengler and Matthes 2018). The latter approach has proven to result in a considerably lower share of workers who show a high risk of computerization. Both approaches seem to have their drawbacks, which we discuss in more detail in our literature review section. In contrast to the recent studies about job automation in Austria by Nagl et al. (2017) and Peneder et al. (2016), our study uses an occupation-based approach to examine the risk of computerization for jobs in Austria. This has the advantage that we are able to examine the Austrian labor market’s susceptibility to computerization on the most detailed aggregation level (ÖISCO-08 4-digit).[2] While Peneder et al. (2016) and Nagl et al. (2017)

[1] The work Frey and Osborne (2017) was already published in 2013 as a working paper. Inspired by this working paper, a series of similar works were created for other countries after 2013.

[2] ÖISCO-08 is the Austrian version of the currently used International Standard Classification of Occupations (ISCO-08). For details on ÖISCO-08 see e.g. Statistics Austria (2011)—for details on ISCO-08 see e.g. International Labor Office (2012).

do not examine single occupations, our study not only identifies problem areas but also shows results for nearly every relevant Austrian occupation. Our detailed results and high labor market coverage (> 93%) allow to create and interpret automation scenarios for specific jobs and areas but also for the Austrian workforce as a whole, which we find especially important to individually develop and apply appropriate measures to secure the future development of the Austrian labor market.

By searching the literature, we formed a basis for a more sober and realistic interpretation of our results. For Austria, Peneder et al. (2016) identify a shift from manual to non-manual tasks. A study carried out by the WEF (2016) shows that the work environment, working hours and the skills required within occupations is expected to change in the near future. Their results further show that new technology is likely to automate only specific tasks, rather than complete occupations (WEF 2016). Spitz-Oener (2006) points out the importance of education and training because of the upcoming changes in our jobs' task profiles due to computerization. Furthermore, Frey and Osborne (2017) discovered a relationship between education and computerization probabilities. On the basis of our comprehensive literature research we come to the conclusion that the task structure, skill and education requirement as well as the working environment in general are subject to change due to computerization in the future, while a complete wipe-out of a considerable amount of occupations seems highly unlikely. Drawing on these findings, we decided to develop a more lenient definition on how to interpret the results we obtain for Austria. According to this definition, we assume that high-risk occupations are very likely to undergo substantial changes regarding task structure, skill and education requirements and general working environment. We suggest that only in the worst case some occupations might be completely automated. With this new definition, we provide a solid tool to create realistic automation scenarios for occupations in Austria. While anxieties are a common side effect of technology change (Decker et al. 2017), historic experience shows that technologic disruption both destroyed and created jobs, and particularly in the long run can have positive effects (Schwarzbauer 2017).

In course of our examination, we first collect employment data for Austrian occupations. Secondly, we translate Frey and Osborne's (2017) results into Austrian occupations. To ensure the best possible comparability, we use the same crosswalks as Frey and Osborne (2014) used for an examination of jobs in the UK (Osborne (2016), personal communication, November 9, 2016). Thirdly, we created a new, more lenient definition in order to interpret the results we obtained. Furthermore, since Frey and Osborne (2017) provide evidence that there is a negative relationship between wages and computerization probability and the Austrian Court of Audit, quoted from Statistics Ausrtia (2014b) show that women earn lower wages than men, we further examined if there is a gender inequality concerning the risk of computerization in Austria. Finally, we interpret our results with the use of our previously mentioned definition. We find that using a clean method like we do in our study is crucial to estimate the future impact of computerization.

In summary, in our study we use an occupation-based approach to provide comprehensive results for occupations in Austria on the lowest possible aggregation level (ÖISCO-08 4-digit level). To obtain these results we used clean data architecture and conducted a clear assignment process. Regarding our occupation-based approach, the use of the same crosswalks as used by Frey and Osborne (2014) ensures the best possible translation of their results (Frey and Osborne 2017; Osborne (2016), personal communication, November 9, 2016). To prevent potential misinterpretations of our results, we wanted to clearly dissociate ourselves from any equation of the technical automation potential of jobs—as defined by Frey and Osborne (2017) and the likelihood of actual computerization or implementation of new technologies. For that reason, we decided to develop a more lenient definition to interpret the results we obtained for Austria. Our results allow assumptions for nearly every relevant occupation in Austria and show 4-digit occupations, as well as 1-digit occupational areas, that are especially affected. We find that our detailed results combined with the basis we built for interpreting them, could be important to develop and determine adequate measures to both counteract future disadvantages of Industry 4.0 on the Austrian labor market as well as to strengthen advantages.

This study is structured in the following way. First, we provide an overview on previous research concerning the computerization of occupations and elaborate on studies for Austria. Afterwards we explain our study in more detail, starting with a comprehensive explanation of the methodology and data used for this paper continuing with the illustration of our results. Subsequently, we explain why and how we developed a new definition to interpret the computerization probabilities we obtained for Austria, in order to finish our study with what we think could be a realistic automation scenario for jobs in Austria as well as a comparison with other studies on this subject.

2 Literature review

In this section, we summarize the most important findings of previous studies concerning the computerization of jobs, starting with a comprehensive explanation of the base study regarding the computerization of jobs conducted by Frey and Osborne (2017) for the US. Table 1 provides a literature overview and points out notable findings.

The study conducted by Frey and Osborne (2017) examines the susceptibility of US jobs to computerization. The authors primarily focus upon identifying the share of jobs that have a high risk of computerization and upon finding possible correlations regarding computerization, wages and education. For this purpose, they developed a new methodology, which they use to estimate the impact of computerization on US occupations. They consider recent developments in technology, most notably, “recent advances in machine learning (ML) and mobile robotics (MR)” (p.254), and the scale to which tasks will be executed by computer-controlled devices. They moreover indicate that new technological advances lead to a rapidly increasing share of non-routine tasks, both cognitive as well as manual, being subject to automation in the future. Frey and Osborne (2017) define their computerization probabilities as follows. Their probabilities represent the automation potential of jobs, “from a technological capabilities point of view” (p.268). The authors “make no attempt to estimate how many jobs will actually be automated. The actual extent and pace

Table 1 Literature overview

Authors, year of publication	Country	Methodology, approach	Employment at risk/Key findings
Bowles (2014a, b)	EU-28	Occupation-based approach	High risk: EU28: 54%; Austria: 54.10% of jobs
Frey and Osborne (2014)	United Kingdom	Occupation-based approach	High risk: 35% of employment; Low risk: 43% of jobs
Pajarinen et al. (2015)	Finland and Norway	Occupation-based approach	Finland high risk: 35% of jobs; Norway high risk: 33% of jobs
Bonin et al. (2015)	Germany	Occupation-based approach and task-based approach	Occupation-based: High risk: 42%; Task-based: High risk: 12% of jobs
Brzeski and Burk (2015)	Germany	Occupation-based approach	High risk: 59% of jobs
Arntz et al. (2016)	21 OECD-Countries	Task-based approach	OECD average: 9%; Austria: 12% of jobs
Peneder et al. (2016)	Austria	Task-based approach	Potential risk for workers in occupations with Manual non-routine emphasis: 12% of jobs
A.T. Kearney Österreich (2016)	Austria	Occupation-based approach	High risk: 44% of jobs
Nagl et al. (2017)	Austria	Task-based approach	High risk: 9% of jobs
Decker et al (2017)	20 European countries	Perceptions about job losses from robot technology using the Eurobarometer Public Attitudes towards Robots dataset	People in jobs subject to higher risk of robotics are more likely to be fearful, particularly in adverse economic conditions and if less protected
Frey and Osborne (2017)	United States	Task model	High risk: 47% of jobs
David (2017)	Japan	Task model	High risk: 55% of jobs
Dengler and Matthes (2018)	Germany	task-based approach	High risk: 15% of jobs
Nedelkoska and Quintini (2018)	32 OECD countries	Task model, based on Survey of Adult Skills (PIAAC)	OECD average: High risk: 14%; Significant changes: 32% of jobs; Large cross-country variance driven by job task organization

Table 1 (continued)

Authors, year of publication	Country	Methodology, approach	Employment at risk/Key findings
OECD (2019)	32 OECD countries	Task model, based on Survey of Adult Skills (PIAAC)	OECD average: High risk: 14%; Significant changes: 32% of jobs; Austria: High risk: 16.6% Significant changes: 29.7% of jobs

of computerization will depend on several additional factors which were left unaccounted" (p.268). Therefore, their results do not allow any assumptions on the actual computerization of jobs or any future implementation of new technologies. It is very important to keep in mind that the authors refer to the technical automation potential, while leaving various other aspects that could influence automation scenarios out of consideration. As time frame for their automation scenario the authors refer to "some unspecified number of years, perhaps a decade or two" (p.265). Especially for high risk occupations the authors seem to expect an automation to happen in the near future.

The methodology used by Frey and Osborne (2017) to calculate computerization probabilities is based on the task model by Autor et al. (2003). In contrast to Autor et al. (2003), Frey and Osborne (2017) suggest that not merely routine tasks are subject to computerization. They argue that the recent technological development allows computers to substitute an increasing amount of non-routine tasks. However, they set some boundaries regarding the computerization of non-routine tasks. These so called "engineering bottlenecks" (p.261) divide labor inputs, that are shielded from computerization into "(1) perception and manipulation tasks, (2) creative intelligence tasks and (3) social intelligence tasks" (p. 261). To estimate the computerization probabilities of occupations in the US, they combined two different approaches, that are both built on the methodology used in previous studies of Blinder (2009) and Jensen and Kletzer (2005, 2010) on the subject of offshoring susceptibility. First, Frey and Osborne (2017) undertook a subjective assessment together with experts. Within this process, they assigned 70 occupations to either category: 1 for automatable or 0 for non-automatable. Regarding this classification process, it is notable that only occupations for those they considered every single task, based on the o*net[3] task and job description, as automatable, were assigned to category 1. For the second approach, they assigned nine suitable objective o*net variables to their previously described bottlenecks. Afterwards, they tested how well their previously mentioned subjective assignment to category 1 or 2 can be explained by these nine chosen subjective o*net variables on the basis of a statistic model. They describe the result as follows: "our algorithm successfully managed to reproduce our hand-labels specifying whether an occupation was computerisable […] our algorithm verified that our subjective judgments were systematically and consistently related to the o*net variables" (p. 265). Based on their algorithm, they were able to estimate the computerization probabilities for all of the remaining occupations.

For the US, Frey and Osborne (2017) find that 47% of the workforce is exposed to a high risk of computerization. The authors expect that these occupations "could be automated relatively soon" (p. 268). Regarding their result, we have to keep in mind that the authors refer to the automation potential "from a technological capabilities point of view" (p. 265), as discussed earlier in this section. They also identified a

[3] o*net: website that provides information on jobs in the US including task and skill profiles, for details see: https://www.onetonline.org/

strong negative relationship between computerization probabilities and wages as well as computerization probabilities and education.

Based on the previously described study by Frey and Osborne (2017), many studies followed that predict the risk of automation for occupations in other countries with the use of either an occupation-based or a task-based approach. While, following Arntz et al. (2016), we refer to studies as occupation-based when specific crosswalks are used to translate Frey and Osborne's (2017) results into other countries' occupation systems (e.g. Frey and Osborne, 2014; Pajarinen et al., 2015), task-based studies mostly create a relationship between Frey and Osborne's (2017) computerization probabilities and the underlying job tasks in order to estimate the risk of computerization for jobs in other countries (e.g. Dengler and Matthes, 2018; Arntz et al., 2016). Both approaches seem to have their drawbacks. While the occupation-based approach is not able to consider task heterogeneity within occupations and the used crosswalks may not always provide a perfect fit, the results obtained with task-based approaches heavily depend on the quality of detailed, national data regarding information on occupations available. Furthermore, task-based approaches mostly provide results only on a less detailed aggregation level than occupation-based approaches, especially when used in countries like Austria, where country-specific detailed task data for single occupations is not available.

Bowles (2014a, b) was the first who uses an occupation-based approach to translate the results of Frey and Osborne's (2017) study, into countries in Europe and estimated that approximately 54.10% of the Austrian workforce is exposed to a high risk of computerization. When comparing Bowles (2014a) results to various other studies that translated the probabilities obtained by Frey and Osborne (2017) into other countries, (e.g. Pajarinen et al. 2015), it is recognizable that he probably overestimated the risk of computerization. The combination of computerization probabilities with EU-28 employment data from the ILO, based on the EU Labour Force Survey and not on country-specific labor data could be one reason for this variance (Bowles 2014a, b).

Given the focus of Frey and Osborne (2017) onto susceptibility of jobs to computerization, we want to stress that where there is risk, there is also chance, there are dynamics in the economy. Just as the upheavals of the Industrial Revolution gave birth to novel structures and jobs, innovations from industry 4.0 may again keep generating new jobs and greater prosperity for many, for example by shifting labor from sectors with low productivity to those with higher particularly in the long run (Acemoglu and Restrepo 2020; EBRD 2018; Schwarzbauer 2017). Wolter et al (2019) and Lorenz et al (2015) provide indications of balanced-to-positive employment effects for Germany, and Kummer et al (2016) for Austrian exports. Thus when discussing effects of industry 4.0 under the notion of "risk of computerization", it is also important to consider this process of creative destruction in Schumpeters positive sense (Schwarzbauer, 2017).

For Austria, Peneder et al. (2016) examined the susceptibility of occupations to computerization on the basis of a task-based approach. Compared to the occupation-approach used in our study the task-based approach has proven to result in a lower proportion of jobs or workforce at risk due to computerization. According to Schwarzbauer (2017), this lower impact for Austria is driven by lower substitution effects of in the Austrian labor market than in the U.S. market underlying the study of Frey and Osborne (2017). Bonin et al. (2015) also argue that the US-specific assumptions are not automatically transferable to every country. They use time series (1995–2015), including data from the Austrian micro-census labor force survey, which label the salaried workforce according to their occupational ÖISCO task profile. Based on this categorization they assigned one activity emphasis to each ÖISCO-08 3-digit level group for Austria. This means that if e.g. one of these groups includes mostly manual routine tasks, it is characterized as manual routine task occupation group. Therefore, their examination considers only the main activity and does not seem to distinguish between e.g. jobs that only carry out manual routine tasks and jobs that mainly include manual routine tasks but also include some cognitive routine and manual non-routine tasks—they label them both as manual routine occupation groups. It is also notable for the interpretation of their results that they only examined changes concerning job requirements on the basis of their main activity emphasis. The results found by them depict that 40% of all ÖISCO-08 minor groups show an emphasis on analytic and interactive non-routine tasks, 15% on cognitive routine tasks and 45% on manual tasks.

According to Peneder et al. (2016), as of 2015, in terms of employment data, 35% of all Austrian employees are assigned to analytical and interactive non-routine tasks occupation groups, 27% are assigned to manual non-routine occupations and 25% are assigned to cognitive routine tasks. The remaining 12% are employed in occupation groups that show an emphasis on manual routine tasks.

A.T. Kearney Österreich (2016) estimate that 44% of the Austrian workforce is exposed to a high risk of computerization. Since the study by A.T. Kearney Österreich (2016) is also an adaption of Frey and Osborne's (2017) study we assume that the authors also use an occupation-based approach for the calculation of computerization probabilities. However, we have to note, that we were not able to receive the full study, therefore, our assumptions and statements are based on a summary we received.

Arntz et al. (2016) examined the computerization probabilities of jobs in OECD countries using a task-based approach. As data basis for their task profiles within occupations in different OECD countries they use the PIAAC database (Programme for the International Assessment of Adult Competencies). The use of this data allows considering task heterogeneities within occupations, according to Arntz et al. (2016). The database includes "a comprehensive list of tasks that people actually perform at their workplace." (p. 12). They conclude, that 12% of the Austrian workforce is exposed to a high risk of computerization. Nedelkoska and Quintini (2018) broaden this analysis to 32 OECD countries and also include workers who lack basic computer skills and/or are in jobs that do not require using a computer. They find a large variation in the mean risk of job automation across countries, ranging from 42% in New Zealand to 57% in Slovakia. With 48%, Austria comes close to the sample mean of 47%. They attribute this cross-country variation in automatability strongly (70%) to differences in the organisation of job tasks within economic sectors, and only by 30% to differences in the sectoral structure of economies.

For Japan, David (2017) examines the labor market using a task model based on Frey and Osborne (2017). The author combines occupation specific data from the database “Career matrix” and the Population Census 2010 from the Bureau of the Ministry of Internal Affairs and Communications. Compared to the 93% of labor market coverage in our study, David (2017) covers 88% of the Japanese employment. To obtain results David (2017) uses the “Random forest” algorithm. Applying the same thresholds as in Frey and Osborne (2017) the results depict that 55% of the Japanese employment is highly susceptible to computerization, approximately 25% show a medium risk, and 19% a low risk of automation. In comparison to our results for Austria, a substantially larger share of Japanese workers seems to be employed in high risk occupations. While in the medium risk category the results for Japan seem to be very similar to the ones we obtained for Austria, the share of Japanese workers in low risk occupations is clearly lower. Furthermore, while we identify a correlation between gender and computerization probability for the Austrian labor market, David (2017) finds no such correlation for workers in Japan.

Bonin et al. (2015) also calculated computerization probabilities for jobs in Germany with the use of a task-based approach, which, as expected, resulted in a much lower share of jobs at risk (12% of jobs), compared to their occupation-based calculation (42% of jobs).

A recent study by Nagl et al. (2017) adopts a task-based approach and concludes that approximately 9% of the Austrian workforce is exposed to a high risk of automation, also way lower than the results of Frey and Osborne (2017) for the U.S. Their results show that the majority of workers are assigned to a computerization probability between 0.4 and 0.65. According to Nagl et al. (2017), the most affected occupational areas are “Elementary occupations”, “Plant and machine operators, and assemblers” and “Craft and related trades workers”. Regarding the number of jobs at risk, “Service and sales workers”, “Plant and machine operators, and assemblers” as well as “Elementary occupations” together include nearly 60% of all workers that are assigned to a high automation probability. According to the authors, workers with low computerization probability are mostly “Managers” (> 60%), “Professionals” (> 16%) as well as “Technicians and associate professionals” (> 15%).

Decker et al (2017) take a different angle. Using the 2012 Eurobarometer public attitudes towards Robots dataset, they assess which members of the labor force are most fearful of the introduction of robots at work. They show that the level of fear goes along the level of risk for robotics, but is also driven by the respective countries´ economic conditions and labor market policies.

According to the OECD Employment Outlook (OECD, 2019) about 16.6% of Austrian jobs are at high risk of automation and 29.7% of jobs are very likely to undergo significant changes in the future. Compared to our results, the OECD study indicates an approximately 10% lower share of jobs that may be affected by radical technological changes. Their results further point out the importance of education and skill development for people that work in jobs with a high risk of automation. According to the OECD, it is essential for Austrian workers that may lose their work to automation to develop the right skill set to be able to be reemployed in new jobs that could emerge due to technological advances. Furthermore, the report states that young workers and those who have not completed a tertiary education face the highest risks in the future. To be prepared for the upcoming labor market challenges in Austria, the OECD suggest a few key actions to be taken by the government. While collective bargaining in Austria is already in a very good state, the focus on adult training as well as an expansion of social benefit levels and payment for non-standard workers may be essential to be prepared for future digitization challenges.

3 Methodology

3.1 Calculation of computerization probabilities

We chose an occupation-based approach to translate Frey and Osborne's (2017) results to occupations in Austria, because it allows us to identify especially affected occupational areas (ÖISCO-08 1-digit groups) as well as specific single occupations (ÖISCO-08 4-digit groups). To obtain computerization probabilities for Austrian occupations, we have to adapt the probabilities obtained by Frey and Osborne (2017) for ÖISCO-08 occupations. The first step involves the collection of labor data for as many Austrian occupations as possible to obtain an especially high coverage of the Austrian labor market. For this, we revert to data from the micro-census labor force survey, conducted by Statistics Austria for 2015 (Statistics Austria, 2016b, c). Afterwards, we select those occupations that can be interpreted statistically. Occupations with more than 3,000 workers fulfill this criterion, all other occupations are not taken into further consideration (Statistics Austria 2016a). Despite these restrictions, we were able to obtain employment data for 222 Austrian occupations on ÖISCO-4-digit level (Statistics Austria 2016b, c).

In a next step, we have to correctly assign the computerization probabilities, obtained by Frey and Osborne (2017), to Austrian occupations. For this reason, it is necessary to accurately translate the different occupation systems used. To ensure the best possible translation and comparability, we use the exact same crosswalks as Frey and Osborne (2014) used to translate their results for the US into occupations in the UK. With the help of Frey and Osborne's (2014) US crosswalk (provided by Osborne (2016), personal communication, November 9, 2016), we first assign the computerization probabilities of all US occupations with a one-to-one equivalent, for which a computerization probability has been examined, to their corresponding ÖISCO-08 occupation. The use of one-to-one correlated occupations allows a direct transmission of US computerization probabilities to Austrian occupations. For ÖISCO-08 minor groups with more than one corresponding US occupation, we calculate the probability by averaging the US data. US occupations with no computerization risk remain unconsidered. Therefore, if e.g. four US occupations are assigned to one ÖISCO 4-digit occupation, but only for 3 of them computerization probabilities are provided, we calculate the average based on the three probabilities available. In this process, we have to merge one of the 222 selected ÖISCO groups for which no probability has been identified.

Due to some obscurities regarding the calculation for the 4-digit level occupations "Generalist medical practitioners" and "Specialist medical practitioners", "Nursing professionals" and "Midwifery professionals" as well as "Chemical products plant and machine operators" and "Photographic products machine operators" we decided to examine these groups on 3-digit level as "Medical doctors", "Nursing and midwifery professionals" and "Chemical and photographic products plant and machine operators". On this aggregation level, we were able to identify definite probabilities and since these minor groups contain no further occupations on 4-digit level, a merge will not result in noticeable inaccuracies.

Based on this procedure we obtained a list of 215 unit groups as well as 3 minor groups including their corresponding employment data as well as computerization risks, which in overall cover more than 93% of the classifiable Austrian labor force. Following Frey and Osborne (2017) we assign our occupations to 3 different risk categories. Those groups for which we obtained a computerization probability of greater than 0.7 (or 70%) are characterized as "high risk", while groups with probabilities of less than 0.3 (or 30%) are described as "low risk". Occupations with probabilities of 0.3 (or 30%) to 0.7 (or 70%) are characterized as "medium risk". Since every occupation is linked to their corresponding number of employees, we are now able to calculate and analyze the number of workers assigned to the 3 risk categories. As stated above, when discussing levels of higher or lower risk, we should not forget about possible positive effects respectively individual or political adaptive capacities as well.

3.2 Gender-specific differences concerning computerization

Frey and Osborne's (2017) study provides evidence of a negative relationship between wages and computerization probabilities of occupations. According to the data from the Austrian Court of Audit quoted from statistics Ausrtia (2014b), provided by Statistics Austria, Austrian female employees have a considerably lower average gross income than men within every ÖISCO-08 major group. Due to this fact, the question arises if this implies a higher computerization probability for women in general. To answer this question, we require specific labor market data. Unfortunately, no gender specific employment data for ÖISCO-08 unit groups were accessible. Therefore, for this specific analysis, we rely on ISCO 3-digit level data from the micro-census labor force survey 2015 by Statistics Austria (2016c). Due to these restrictions, we have to extrapolate our computerization probabilities to the exact same aggregation level to examine a possible correlation between gender and computerization probability. We achieve this by calculating the average computerization probability per capita for every ÖISCO-08 minor group. Afterwards we use 2 different approaches to examine possible gender-specific inequalities. First, we assign these minor groups to our previously defined three risk categories. This allows us to analyze the distribution of females compared to the distribution of men within the different risk categories. Secondly, we analyze single minor groups. Within this context, we examine if there is a positive correlation between the proportion of females within occupations and the risk of computerization.

4 Data

Employment data used in this study is based on the definition of "employed", "self-employment" and "paid employment" (employees) adopted by the International Labour Organisation (International Labour Organisation 1982). The source of our employment data used for the calculation of computerization probabilities as well as for our examination of a potential gender difference with regard to susceptibility to computerization is the micro-census labor force survey, carried out by Statistics Austria for 2015 (Statistics Austria 2016b, c). This census is a quarterly sample survey, based on a rotating panel design, which includes approximately 20,000 private households (Meraner et al. 2015). According to Statistics Austria (Statistics Austria 2016a), the "employed" in our data set refer to the International Labour Organisation (1982) definition, include recipients of child care allowance or parental leave pay and exclude people in institutional households, compulsory military service or alternative civilian service. Therefore, when we use the terms "labor market" and "workforce" we refer to the "employed" as defined by the International Labour Organisation (1982), with the restrictions according to Statistics Austria (2016a).

All statements and data concerning the income and wages of Austrian workers are based on the earnings report 2014, published by the Austrian Court of Audit (2014a, b), and refer to Austrian "paid employment" (employees) at the age of 15 or above in 2013, excluding apprentices. The same applies for employment data concerning the examination of a possible correlation between wages and computerization data. Data regarding gender-specific wage data further also include armed forces occupations, as stated in the earnings report (Austrian Court of Audit, quoted from Statistics of Austria 2014b). All employment and wage data used from the earnings report 2014 of the Austrian Court of Audit (2014a, b) are provided by Statistics Austria and come from the wage tax statistics and micro-census labor force survey as well as insurance data from The Organization of Austrian Social Security (Austrian Court of Audit 2014a, b).

As from 2015, the Austrian labor market comprises 4,148,400 people (Statistics Austria, 2016c). Every Austrian job, and therefore every Austrian worker, can be classified to one of 436 ÖISCO-08 unit groups (Statistics Austria, 2011). Unit groups, also referred to as 4-digit occupations, represent occupational groups on the lowest aggregation level (Statistics Austria, 2011).

As usual, data granularity and subsample size is an issue. Occupations with less than 3,000 workers cannot be interpreted statistically and therefore must be excluded from our analysis (Statistics Austria 2016a). Our data set also includes some occupations with less than 6,000 workers which are subject to strong random loading (Statistics Austria 2016a). However, occupations with less than 6,000 workers only represent about 7.5% of our considered workforce.

Overall, this study considers 221 of 436 unit groups. These are 215 unit groups and three minor groups. Minor groups are occupational groups on a higher aggregation level (Statistics Austria, 2011). The 3 minor groups we included in our study embody each only 2 unit groups for these an examination was only possible on a higher aggregation level. Even though we also had to exclude a few small occupations for which the access to employment data was denied or associated with high costs, our data comprises more than 3.8 million people, and therefore represents more than 93% of Austria's classifiable labor market, based on the average for the year 2015 (Statistics Austria 2016b, c). This high coverage allows comprehensive analyses and interpretations for the majority of Austrian workers.

For our examination, we used the same crosswalks as Frey and Osborne (2014) used for their study to calculate the probabilities of computerization for jobs in the UK. For the purpose of mapping their results, Frey and Osborne (2017) used crosswalks that are slightly adapted versions of those published by the U.S. Bureau of Labor Statistics (2012a, 2012b) at the behest of the Standard Occupational Classification Policy Committee (SOCPC), which contains a mapping of US occupations to ISCO-08 occupations and the mapping document published by the Office for National Statistics (2013), which converts jobs from the UK SOC-2000 job classification scheme into the ISCO-08 format (Osborne (2016), personal communication, November 9, 2016). The use of exactly these crosswalks ensures a clear assignment process as well as the best possible comparability of our results for Austria to the studies for the US and the UK carried out by Frey and Osborne (2014, 2017).

5 Results

5.1 General

As described above, following Frey and Osborne (2017) we assigned Austrian jobs to three different risk buckets according to their computerization probability. An allocation based on this principle reveals that more than 40% of the Austrian employment (equals more than 1.5 million workers), is exposed to a high risk of computerization. Particularly for "Clerical support workers", "Service and sales workers" as well as "Craft and related trade workers" we find that they can be described as highly affected. These 3 ISCO-08 major groups include more than 72% of all people who work in high-risk occupations. Proportionally, "Clerical support workers" are most gravely affected. Within this major group, more than 95% of the workforce is exposed to high risk of computerization. With only approximately 28%, the Austrian labor market contains a relatively small proportion of workers within the low-risk area. Employees within the major groups "Managers" and "Professionals" are rather exposed to a low direct risk of computerization. "Technicians and associate professionals" also comprise a large number of workers in low-risk occupations. However, the vast majority of this major group is assigned to the medium-risk category in terms of their computerization probabilities. Jobs that are least susceptible are "Dieticians and nutritionists", "Education methods specialists", "Hotel managers", "Psychologists" and "Education managers".

Frey and Osborne (2017) find evidence for a negative relationship between wages and the computerization probability of occupations in the US. The Austrian court of audit quoted from Ststistics Austria (2014b), who uses data provided by Statistics Austria, shows that within the categories "blue collar workers", "civil servants" as well as "white collar workers", persons who carry out highly qualified and leading tasks earn a considerably higher annual gross middle-income than workers who carry out auxiliary or semiskilled activities. According to Bonin et al. (2015), the 2003 PIAAC survey shows that German managers frequently carry out analytical and interactive tasks. This can be seen as indication for a lower computerization probability, since Autor et al. (2003) identified a positive relationship between computerization and non-routine analytical as well as interactive tasks. Furthermore, Frey and Osborne (2017) provide evidence of a negative correlation of wages and computerization probabilities. Because of these findings, we speculate that the negative relationship holds generally and is therefore also applicable for Austrian occupations.[4]

In the following section, we first take a closer look at the results of each ISCO-08 major group in particular. A detailed list including all occupations (on ÖISCO-08 4-digit level) and their corresponding computerization probability as well as a graphic preparation of our results are available upon request.

5.2 Major group 1: "Managers"

Starting with major group 1 "Managers", regarding computerization, the majority of these is only slightly affected. However, "Managers" represent only about 4% of the Austrian labor market (Statistics Austria, 2016c). This might be because of the exceptionally high level of required education and qualifications, since Frey and Osborne (2017) provide evidence of a relationship between education and computerization probabilities. As mentioned before, we assume that there is a negative correlation between wages and computerization probability. The annual gross middle-income of an Austrian employee amounts to approximately EUR 26,400 (Austrian Court of Audit quoted from Statistics Austria, 2014b). Considering that "Managers" earn an annual gross middle-income of more than EUR 60,000, which is by far the highest of all major groups, this result is in accordance with previous studies (Austrian Court of Audit quoted from Statistics Austria, 2014b).

5.3 Major group 2: "Professionals"

As well as in Major group 1, the majority of "Professionals" work in occupations categorized as low-risk occupations. Overall, this group represents about 16% of the Austrian workforce (Statistics Austria 2016c). "Professionals" represent the largest major group, in terms of employment data, that have a low probability of computerization. As the occupational title suggests, this major group almost entirely includes occupations that require high qualifications and therefore consequently, a high level

[4] This describes a tendency or a trend, but there are also significant deviations from the trend. We can find significant differences in income per capita between occupations with very similar computerization probabilities. When interpreting this relationship one should keep in mind that the estimated probabilities show purely technical (and not economic) potentials or possibilities. Therefore, more expensive workers do not automatically have higher probabilities. One can rather expect that occupations with lower technical replacement probabilities have by tendency higher income.

of education. Like "Managers", "Professionals" earn a relatively high annual gross middle-income of more than EUR 40,000, which is approximately EUR 14,000 above-average (Austrian Court of Audit quoted from Statistics Austria 2014b).

5.4 Major group 3: "Technicians and associate professionals"

"Technicians and associate professionals" represent a group with very varying computerization probabilities, while overall, they include nearly 20% of the Austrian employment (Statistics Austria 2016c). Nevertheless, most of the employees within this group tend to be assigned to the medium and low risk category. Noteworthy jobs with a high risk of computerization are e.g. "Accounting associate professionals" and "Electrical engineering technicians". These unit groups are characterized with especially high automation probabilities. "Accounting associate professionals" include over 36,000 employees and are assigned to a computerization probability of approximately 0.96, while "Electrical engineering technicians" employ over 27,000 workers that are exposed to a risk of about 0.83 (Statistics Austria 2016b). The largest unit group, which has a low risk of computerization, are "Nursing associate professionals". This group employs approximately 91,800 workers who are assigned to a probability of only approximately 0.06 (Statistics Austria 2016b). "Administrative and executive secretaries" represent the largest group of workers within major group 3. More than 100,000 workers are assigned to this group, which is characterized as medium risk (Statistics Austria 2016b). The annual gross middle-income of "Technicians and associate professionals" is EUR 33,253, and therefore, above the Austrian average (Austrian Court of Audit, Quoted from Statistics Austria 2014b).

5.5 Major group 4: "Clerical support workers"

This major group is by far the most susceptible in terms of computerization. Over 96% of "Clerical support workers" are exposed to a high risk of computerization. Since this major group includes more than 10% of the Austrian workforce, substantial changes and extensive automation of a wider range of tasks within these occupations could have a major impact on the labor market (Statistics Austria 2016c). This consequently represents a high-risk potential. In detail, the situation can be described as very critical, because more than 330,000 employees are assigned to an extremely high probability of computerization of 0.9 min. Especially "General office clerks" represent a unit group with more than 180,000 workers with a corresponding probability of approximately 0.96 (Statistics Austria 2016b). "Clerical support workers" have an annual gross middle-income of EUR 23,697, which is slightly under-average (Austrian Court of Audit quoted from Statistics Austria, 2014b).

5.6 Major group 5: "Service and sales workers"

Like "Clerical support workers", "Service and sales workers" are highly susceptible of computerization. This also represents a challenge, since this major group includes 284,100 workers, which equals 7% of the Austrian employment, who are exposed to a computerization probability of more than 0.9. This is mainly because of the large number of workers assigned to the unit group “Shop sales assistants”. The 237,500 people within this group are exposed to a risk of over 0.94 (Statistics Austria, 2016b). Occupations that are least susceptible to computerization within this major group are “Shop keepers”, “Shop supervisors”, “Child care workers” and “Police officers”. Overall, these four occupations represent about 11% of the employees in this major group (Statistics Austria 2016c). The annual gross middle-income of “Service and sales workers” is EUR 15,799, which is well below the Austrian average (Austrian Court of Audit, quoted from Statistics Austria 2014b).

5.7 Major group 6: “Skilled agricultural, forestry and fishery workers”

This major group represents less than 5% of the Austrian workforce (Statistics Austria 2016c). Nevertheless, we must note that “Skilled agricultural, forestry and fishery workers” are rather strongly susceptible to computerization. Within major group 6 “Livestock and dairy producers” as well as “Mixed crop and animal producers” are the largest unit groups, in terms of employment, which include collectively over 110,000 workers (Statistics Austria 2016b). Like “Service and sales workers”, “Skilled agricultural, forestry and fishery workers” earn less than average. Their annual gross middle-income amounts to EUR 16,658 (Austrian Court of Audit quoted from Statistics Austria 2014b).

5.8 Major group 7: “Craft and related trade workers”

As well as the previous two major groups, “Craft and related trade workers” include only a few occupations that have a low risk of computerization. Over 59% of all “Craft and related trade workers” are exposed to a high risk. Therefore, this also involves a certain risk for the labor market, since this major group includes about 13% of the Austrian workforce (Statistics Austria, 2016c). Unit groups like “Cabinet-makers and related workers”, “Brick layers and related workers” as well as “Metal working machine tool setters and operators” each include more than 25,000 people that are exposed to an automation probability of at least 0.82 (Statistics Austria, 2016b). Despite having a high risk of computerization, which should indicate a higher computerization probabilities according to Frey and Osborne (2017), workers within this group earn above average. The annual gross middle-income of “Craft and related trade workers” amounts to EUR 31,116 (Austrian Court of Audit, quoted from Statistics Austria 2014b).

5.9 Major group 8: “Plant and machine operators, and assemblers”

The majority of workers within this group is assigned to a medium risk of computerization. A notable characteristic of this group is that it contains only workers who have a medium to high risk concerning technical automation. Overall, only about 5% of the Austrian workers are assigned to this major group (Statistics Austria 2016c). Generally, the probability of computerization amounts to at least 0.4 within this group. Even though workers within this group are assigned to the medium and high risk category only, they show an annual gross middle income of EUR 29,771, which is similarly to "Craft and related trade workers" above the Austrian average (Austrian Court of Audit quoted from Statistics Austria 2014b).

5.10 Major group 9: "Elementary occupations"

Like major group 8, "Elementary occupations" represents a medium to high-risk occupational area. More precisely, workers who are exposed to only a low risk of computerization are non-existent within this group, based on the observed workforce. "Elementary occupations" include about 8% of the Austrian workforce (Statistics Austria, 2016c). Their annual gross middle-income amounts to EUR 14,546, which is the lowest of all ÖISCO-08 major groups. (Austrian Court of Audit, quoted from Statistics Austria, 2014b).

5.11 Gender differences with regard to being affected by computerization

Our analysis on basis of ÖISCO-08 minor groups shows certain gender inequalities regarding the risk of computerization. For our interpretation, we have to keep the used aggregation level in mind. The following results show the amount of male and female workers and the corresponding computerization risk on 3-digit level. Therefore, it is possible that e.g. some men or women who actually work in a low-risk unit group occupation are assigned to a high-risk minor group and vice versa. In short, the following statements are based on ÖISCO-08 minor groups and have rather limited validity for single unit groups.

When comparing the distribution of men to the distribution of women within the 3 risk categories, we clearly recognize gender-specific inequalities. While the low risk category shows only marginal differences for both genders, the inequalities in the medium and high risk category are considerable. While the largest number of men is employed in medium risk minor groups, the percentage of women who are assigned to the medium risk category is clearly lower. Furthermore, with approximately 46%, the majority of female workers are exposed to a high risk of computerization, while only 36% of all male workers are assigned to this category (see Fig. 1). These effects may also be influenced by sectoral effects. For example, the EBRD (2018) argues that deindustrialization has increased gender segregation further, because male workers leaving manufacturing and agriculture typically went into the major-male sector of construction, while women rather moved into non-market services like education or public administration. For further research on gender effects of industry 4.0, it would also be interesting to test if this inequality has something to do with education, e.g. if there are proportionally more men than women who receive or completed Industry 4.0 focused training or education.

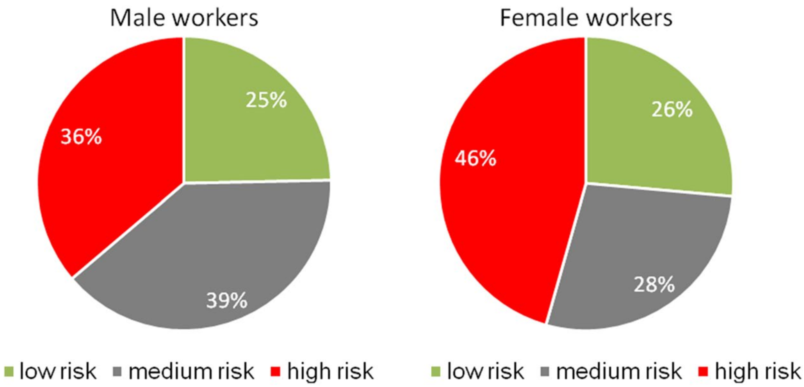

Fig. 1 Comparison: female workers and male workers according to the three computerization risk categories, based on ÖISCO-08 minor groups

6 Discussion

6.1 More lenient definition for probabilities by Frey and Osborne (2017)

Frey and Osborne (2017) define their results, and therefore their calculated probabilities of computerization, as risk percentages that express the likelihood of technical automation for particular occupations in the future. Bonin et al. (2015) criticize that Frey and Osborne indirectly equate technical automation potential and the actual computerization of jobs. Some studies that built on Frey and Osborne (2017) also seem to imply that jobs assigned to a high computerization probability are very likely to be automated in the near future (e.g. Brzeski and Burk 2015). However, as already described, Frey and Osborne (2017) do not estimate the actual computerization of jobs, since there are various other aspects to be considered besides the technical automation potential. Therefore, to avoid misinterpretations, we created a basis for interpreting the results of our study that is composed as follows. The following paragraphs give an overview on how we built our definition and the underlying literature that supports our argumentation.

Spitz-Oener (2006) examined skill changes within occupations for West Germany. The author concludes that changes in skill requirements, especially towards interactive and analytical and away from both routine manual and routine cognitive task requirements, were significantly more intense within occupations that experienced a fast computerization. Furthermore, Spitz-Oener (2006) identified a "sharp increase in non-routine cognitive tasks" (Spitz-Oener 2006, p. 2), while "most of the task changes have occurred within occupations and they have been most pronounced in occupations that have heavily introduced computer technologies" (Spitz-Oener, 2006, p. 2). Accordingly, tasks are subject to computerization, rather than whole occupations.

Pfeiffer and Suphan (2015) bring in the factor "experience" as a key.attribute which should be considered when estimating a potential computerization of the workforce. With experience the authors mean the unique skill of a human to cope with imponderables and situational complexity within a working environment.

The Future of Jobs Survey, conducted by the World Economic Forum (WEF 2016) also concludes that skill requirements will change and that the frequency of changes in these requirements will increase. It is notable that this survey is very comprehensive, including international leading employers, which represent over 13 million workers of various industrial sectors. These statements are especially interesting since these employers play an important role regarding the implementation and evolvement of technological advances in terms of Industry 4.0. Furthermore, the WEF (2016) state that technological advances are not very likely to wipe out complete occupations, but will rather lead to an automation of some tasks within occupations, which would shift the emphasis of workers towards other tasks. The WEF (2016, p. 6) further identified "changing work environments and flexible working arrangements" as top driver of change.

Autor (2015a) state, that "tasks that cannot be substituted by computerization are generally complemented by it […] productivity improvements in one set of tasks almost necessarily increase the economic value of the remaining tasks" (Autor 2015a, p. 136). He further restricts his hypotheses to workers who do not primarily carry out tasks that are subject to automation (Autor, 2015a). Peneder et al. (2016) also argue that the wipeout of whole occupations because of digitization seems to be unlikely.

Based on these findings, we argue that it is more likely that the task profiles as well as skill requirements are subject to change within occupations due to computerization, rather than the complete wipeout of a considerable amount of occupations. We suggest that only in the worst-case occupations may go extinct. Therefore, we presume that occupations for which we assigned a high risk of computerization are especially likely to undergo changes in their task profile as well as skill requirements. Consequently, we also assume that the workers in high-risk occupations will be more gravely affected by these changes in comparison to workers in medium or low-risk occupations. This could also mean a higher risk of a potential job loss, if workers were not able to fulfill future requirements. However, when we point to the risk of a job loss this not necessarily translates into the risk of lower total employment in Austria.

Acemoglu and Autor (2011), Autor (2015a, b) and Spath et al. (2013), among others, discuss potentially important future skill requirements. Acemoglu and Autor (2011) as well as Autor (2015a, b) point out the remaining difficulties of automating skills that require tacit knowledge, mentioning flexibility as one example. Spath et al. (2013) also mention "human" flexibility as future key skill for workers in the production sector, because technology is not very likely to reach the same level of flexibility in the near future. They also refer to changes regarding working hours (Spath et al. 2013). Following Spath et al. (2013) we also argue for a possibly higher risk of a change in terms of working hours towards higher flexibilty within occupations that show a higher risk of computerization.

Frey and Osborne (2017) provide evidence of a relationship between education and computerization probabilities. Similarly, Spitz-Oener (2006) emphasizes the importance of education and training because of the changes in task structure within occupations. We follow these approaches and suggest that the training routes and education requirements may be subject to change.

We also speculate that occupations, to which we assigned a high risk of computerization, may have a lower labor demand because of their higher technical computerization potential according to the probabilities of Frey and Osborne (2017). For Austria, Peneder et al. (2016) identified a gradual shift of employment in terms of proportions from occupations with an emphasis on manual non-routine tasks to occupations with an emphasis on analytic and interactive non-routine tasks. However, we refer to it as potentially more likely for occupations that show a high risk of computerization, while keeping in mind that according to Autor et al. (2015b) automation substitutes workforce, but also "complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply" (Autor 2015b, p. 5). Furthermore, we refer to Bessen (2015) for an interesting example.

Furthermore, we assume that a shift of workforce across occupations is more likely to happen than the computerization of a considerable amount of whole occupations. Along this line, Wolter et al. (2015) for example predict that the extent of labor force relocations between branches and occupations will be considerably higher than the change in total employment due to the technical advances of Industry 4.0.

Bessen (2015, p. 2) provides evidence that "Employment grows significantly faster in occupations that use computers more". Like Autor et al. (2015b), Bessen (2015) states that "automation can increase demand for the affected occupation as well as decrease demand" (Bessen, 2015, p. 5). Bessen (2015) mentions bank tellers as an interesting example. While Frey and Osborne characterize "Tellers" as high-risk occupations with a probability of 0.98, Bessen (2015) shows that the employment data of human bank tellers increased since the implementation of Automated Teller Machines (ATMs). As a reason Bessen (2015) identified the decrease in operating costs caused by ATMs, which allowed banks to open more branches and subsequently, hire more bank tellers in the earlier days of automation. "Technology alone did not determine whether employment of tellers grew or fell; economics mattered" (Bessen, 2015, p. 5). The WEF (2016) particularly stresses that effects of industry 4.0 and of technological progress in general are not exogeneous. Economics matter, and thus actions by individuals as well as by political actors do play a role. Schwarzbauer (2017) thus emphasizes the need for timely and adequate responses by politics and society at large.

To sum up, the goal of our analysis is not an exact estimation of the amount of occupations that could be non-existent because of computerization hereafter, but we rather want to examine the potential impact and future changes due to computerization regarding the Austrian labor market. For this purpose, we built a lenient definition to interpret the results we obtained for Austria in a sober way, which we determine as follows. In this study the "probability of computerization" describes the likelihood and intensity of changes within a particular Austrian occupation as a result of technical advances in the future. We do not assume that occupations that have a high risk of computerization are automatically more likely to be completely automated. We rather estimate that high-risk occupations are most likely to undergo and/or be affected by substantial changes due to automations in the future. By changes we refer to aspects discussed earlier, i.e. alterations concerning the (1) working environment and working hours, (2) changes in the task profile and skill requirements, (3) changes in education and other job requirements that a worker has to comply with in the future to be able to practice a specific profession, as well as a resulting potential (4) lower labor demand in occupations where a significant number of tasks is subject to computerization. Furthermore, we presume that for workers within occupations with a very high probability of computerization it is therefore especially difficult and associated with more effort to ensure steady employment in the future. We also assume that Industry 4.0 focused skills and education will grow in importance. Moreover, we suggest that technological progress is more likely to shift the emphasis of an occupations' task profile to tasks that are more likely to be sheltered from computerization, rather than causing the extinction of whole occupations. Nevertheless, since we cannot accurately predict the future process of technological advances, we are not able to rule out that some occupations that face a very high risk of computerization may be subject to complete computerization in the future. Again, this may also provide positive triggers, if the change is taken as an opportunity for timely action.

6.2 Interpretation of results

Our results show that more than 40% of the Austrian workforce is exposed to a high risk of computerization. This implies that more than 1.5 million workers are very likely to be affected by significant changes due to computerization. According to our definition the ÖISCO-08 minor groups to which these people are assigned, are very likely to undergo substantial changes in terms of the tasks carried out and the skills required for a particular occupation in the future. For workers in these occupations this could mean a higher risk to lose their job, because of lower labor demand, or to get replaced by workers with Industry 4.0 focused skills and education. Furthermore, these occupations are more likely to experience changes in working hours—especially towards higher flexibility.

Especially major group 4 ("Clerical support workers") is very likely to be affected by technological changes. Workers within this group have a very high average computerization probability. Therefore, this occupation is also more likely to have lower labor demand in the future, according to our definition. For these "Clerical support workers" it is therefore essential to adjust their skill profile to prevent a potential job loss.

Regarding our results, we think that the high proportion of Austrian workers within the high-risk category points out the need for advanced training for people employed in high-risk occupations to fulfill future task requirements and therefore to prevent job loss. Therefore, we suggest that Austria should refocus the educational system in line with requirements by Industry 4.0-technology to accommodate the accelerating technological process.

However, the predicted shift can also be seen as a chance for both workers as well as a country's economy. The shift from occupations with a manual task emphasis to occupations with a non-manual task emphasis in Austria, as shown by Peneder et al. (2016), may opens chances for people with education that is prone to computerization to climb the occupational ladder. This notion is particularly relevant for occupations high in interactive and analytic non-routine tasks, as identified by Peneder et al. (2016). Fortunately, the share of routine tasks in Austria is lower than e.g. in the U.S., particularly in the services sector and industrial manufacturing (Schwarzbauer 2017). Furthermore, an examination for jobs in the UK shows that "over the last 15 years, automation has created approximately four times as many jobs as it has lost.“ (Deloitte 2015, p. 3). Their analysis also depicts a shift of workforce from occupations for which they identified a high risk of computerization to occupations that have a low risk of computerization, within the same period (Deloitte 2015). Experts of the Centre for Curriculum Redesign, whose work lays the focus on future education, for example estimate in a report of a roundtable discussion concerning the future impact of technology "just as it has in the past, technology will eliminate some jobs for human beings while creating the conditions for emergence of others." (Fadel 2014, p. 3). Based on Frey and Osborne (2017), A.T. Kearney Österreich (2016) estimates that new occupations are most likely to emerge in knowledge-intensive and creative sectors like education or healthcare. Another interesting point is that the ongoing digitization could have a positive impact on our economy. While Düll et al. (2016) expect that the impact on GDP is rather limited, McKinsey Global Institute (2016) estimates that digitalization may be able to increase Europe's GDP by approximately EUR 2.5 trillion in 2025.

Since we cannot rule out that the possible emergence of new jobs may be able to employ a significant number of workers, as we are not able to accurately predict the future impact of computerization, we obviously cannot completely preclude the possibility of complete automation for whole occupations either. Especially the future job chances of workers within the ÖISCO-08 unit groups to which the highest computerization probabilities were assigned (e.g. most "Clerical support workers"), may be limited. The unit groups for which we identified the highest computerization risks are "Contact centre salespersons", "Clearing and forwarding agents", "Accounting associate professionals", "Shop sales assistants", "Packing, bottling and labeling machine operators" and "Legal secretaries". For workers within these occupations it seems to be very likely that their work routine and their working environment as well as the skill requirements are subject to substantial change in the next decade or two. Some examples for occupations that are most likely to have the biggest impact on the Austrian labor market, due to their considerable number of workers employed in combination with a very high probability of computerization, are: "Shop sales assistants", "General office clerks", "Waiters" and "Accounting and bookkeeping clerks".

According to our results, approximately 28% of the Austrian workforce is exposed to a low risk of computerization. Therefore, we predict that it is very likely for workers in the low risk category that they will undergo only comparatively marginal changes of their job profile and requirements. This means that within these occupations the main tasks carried out, the education required as well as the employment data are more likely to remain steady. The unit groups which have the lowest risk of computerization are: “Dieticians and nutritionists”, “Education methods specialists”, “Hotel managers”, “Psychologists”, “Education managers”, among others.

It is important to counteract the potential negative aspects of Industry 4.0 in Austria. The WEF (2016) states, that since the acquisition of cognitive abilities is a much longer process, it is on the government to provide the educational framework for future job requirements. The WEF (2016) further suggest that companies should assist the government to identify and define their future need of human workforce in their own best interest. Companies should also work in close cooperation with educational institutions and actively communicate the basic skills necessary to satisfy the requirements of the future world of work.

As an important action to prevent negative Industry 4.0 problems to arise, the Austrian ministry for transport, innovation and technology (BMVIT 2016) recently founded the association “Industrie 4.0 Österreich–die Plattform für intelligente Produktion” (Industry 4.0 Austria–the platform for intelligent production), which is designed to examine the process of digitization as well as to work out solutions for Industry 4.0 related issues. Furthermore, it will provide an Industry 4.0 check for companies, to screen their business to find out if they are ready for the future of Industry 4.0 and which actions they have to take for the conversion to a digitized company (BMVIT 2016).

Regarding our gender-specific examination, our results show that female workers are more affected than men, regarding substantial changes at their workplace. Approximately 46% of female workers are assigned to a high risk of computerization, while only about 36% of men are exposed to a high risk. These results suggest considerable gender inequalities in Austria. Compared to men, more women work in occupations that are very likely to be subject to considerable changes. For future studies, it could be interesting to examine if there are more men than women who currently receive or already completed Industry 4.0-focused training in Austria, to explain our identified inequalities.

6.3 Comparison with and discussion of other studies (in Austria)

Bowles (2014a, b), who was the first to obtain computerization probabilities using an occupation-based approach to translate the results by Frey and Osborne (2017) into EU countries, estimated that 54,10% of Austrian workers are exposed to a high risk of computerization. Compared to our result, Bowles (2014a) estimates a share which is about 14% higher. However, as mentioned before, if we compare his results with other studies concerning computerization probabilities of jobs in EU countries which use a similar methodology, Bowles (2014a) generally seems to overestimate the number of jobs at risk.

Peneder et al. (2016) conducted a study examining the task emphasis on jobs in Austria on ISCO 3-digit level using a task-based approach. Drawing on Dengler and Matthes (2018) they point out that routine tasks are completely automatable, while in terms of analytical tasks the human workforce can only be supported with the use of computers. Currently, manual non-routine tasks cannot be completely automated, according to Dengler and Matthes (2018). Therefore, we interpret the conclusions drawn by Peneder et al. (2016) as indications that approximately 12% of Austrian workers may be exposed to a potentially high risk of computerization. Compared to our results, the much smaller proportion of workers with a high risk is in line with expectations since Peneder et al. (2016) used a task-based approach, which is generally associated with lower computerization probabilities.

Peneder et al (2016) further come to the conclusion that non-routine occupations will be in demand in the future. However, Dengler and Matthes (2018) also depict that in the future it may be possible that tasks that are currently considered as non-routine tasks, may be converted to routine tasks, due to technological advances.

Compared to our study, Peneder et al. (2016) only examine occupations on 3-digit level and do not quantify the number of jobs which may be exposed to a certain risk of computerization. Furthermore, they focus on the main task emphasis of 3-digit occupations, while leaving all other tasks which workers in these occupations may carry out unconsidered. Our study in comparison rather focuses on the international ISCO task profiles which cover up a variety of tasks for 4-digit occupations and a methodology which quantifies the number of workers who are exposed to a high risk of computerization. Our methodology therefore allows more precise conclusions and assumptions for 93% of the Austrian workforce.

Furthermore, the time series used by Peneder et al. (2016) display that the employment of occupations that mainly contain analytical and interactive tasks, increases proportionally, while the employment of manual non-routine occupations becomes successively less important. Their time series also show a proportional shifting of employment from manual occupation groups to non-manual and therefore analytical cognitive and interactive occupation groups, while the proportion of employment in routine compared to non-routine occupations remained constant (40–60%). These findings by Peneder et al. (2016) can also be seen as changes according to our definition on how to interpret the computerization probabilities by Frey and Osborne (2017). Another notable finding of this study is, that the examination could not identify a polarization effect regarding Austrian occupations (Peneder et al. 2016). However, there are also previous studies (e.g. Goos et al. 2014 or De la Rica and Gortazar 2016) that provide contrary results regarding polarization in Austria than those shown by Peneder et al. (2016).

A recent study, published by A.T. Kearney Österreich (2016), which uses an occupation-based approach that is probably very similar to the one used in this study, arrives at the conclusion that, approximately 44% of all Austrian workers are exposed to a high risk of computerization. This proportion is very similar to the results of our examination. Reasons for the slightly higher share of workers who have a high risk of computerization may be a possible use of the officially published crosswalks or a different the translation methodology. These provide a better fit and thus were applied in our own empirical investigation. A.T. Kearney Österreich (2016) mentions occupational groups as examples for groups that are exposed to an especially high risk of computerization. Since they did not use ÖISCO-08 terms to describe them, we assume that general and keyboard clerk, sales workers, agricultural workers, metal workers and some others are assigned to high computerization probabilities, which, generally speaking, complies with our results when roughly translating the terms to ÖISCO-08. We recognize slight deviations for example regarding agricultural workers. Since our results show some occupations with a medium risk and some with a high risk of computerization, we could not generally categorize agricultural occupations as especially affected. However, A.T. Kearney Österreich (2016) did not refer to the ISCO-08 occupations in their examples for affected occupations and therefore, may have used another system to form occupation groups. Occupations that are labeled as not affected are for example managers, elderly care occupations, child care and education occupations, nursing occupations and some other. This also corresponds roughly to our results, while keeping in mind that we used ISCO-08 to describe our occupation groups. Moreover, it is notable that their study mentions trends regarding domains where new jobs are expected to arise. These are for example occupations in the sector of health and nurture, environment and sustainability, education as well as in the IT sector. As already mentioned, we have to keep in mind that all statements in our study are based on a summary of the study conducted by A.T. Kearney Österreich (2016), since we were not able to access the full version.

Another study carried out by Arntz et al. (2016) finds that 12% of the Austrian workforce is employed in occupations that have a high risk of computerization. This study uses a task-based approach. The authors use PIAAC-data, which includes a wide range of tasks for every occupation and allows them to consider task heterogeneities within occupations. Since this kind of data is only available at the ISCO 2-digit level according to Arntz et al. (2016), the validity of their statements seems to be limited to this aggregation level. Therefore, we cannot draw assumptions for ISCO-08 minor and unit groups. Our study in comparison shows the impact of computerization of nearly every relevant occupation in Austria. While the scale of impact and also the interpretation of computerization probabilities are open to dispute, our results allow the comparison of single occupations. This is also important to evaluate the potential impact of computerization and further to adopt appropriate measures for single occupations. Compared to the OECD average of 9%, the Austrian workforce is exposed to an above-average and with 12% even is exposed to the highest risk of computerization of all examined OECD countries.

Nagl et al. (2017) come to the conclusion that approximately 9% of the Austrian workforce is exposed to a high automation risk. Interestingly, the authors also mention that if they would slightly lower the minimum percentage that defines a high-risk occupation from 0.7 to 0.6, instead of 9% nearly 40% of all workers would be assigned to a high automation risk. In that case, the results by Nagl et al. (2017) would not be that different to the ones we obtained in our study. According to Nagl et al. (2017), the most affected occupational areas are “Elementary occupations”, “Plant and machine operators, and assemblers” and “Craft and related trades workers”. Regarding the number of jobs at risk, “Service and sales workers”, “Plant and machine operators, and assemblers” as well as “Elementary occupations” together include nearly 60% of all workers that are assigned to a high automation probability. Workers with low computerization probability are mostly “Managers” (> 60%), “Professionals” (> 16%) as well as “Technicians and associate professionals” (> 15%).[5]

[5] A comparison of our study with Nagl et al. (2017) with regard to the average probabilities instead of the proportion of employees with the highest probabilities shows that the results of both studies are quite similar.

Last but not least, we want to reflect on Frey and Osborne's (2014) study regarding the computerization risk of occupations in the UK. Since we made use of the same crosswalks as Frey and Osborne (2014), the results of their study in the UK are especially interesting to analyze and compare with our results for Austria. Frey and Osborne (2014) estimate that 35% of workers in the UK are exposed to a high risk of computerization, while a high proportion of 43% is assigned to the low risk category. When comparing their results for the UK to our results for Austria, the overall result, especially the proportion of workers with a low risk of computerization, is remarkably better. If we look at all three risk categories, it is notable that workers in the UK seem to be either exposed to a low risk of computerization or categorized as high-risk occupations, while Austria in comparison shows a considerable number of workers assigned to the medium-risk category (32%) as shown in our results. For the UK, occupations that have the highest risk of computerization are in "administrative support work; sales and services; transportation; construction and extraction; and production (manufacturing)" (Frey and Osborne, 2014, p. 9). Overall, our results go in line with Frey and Osborne's results for the UK, since we also identified "Clerical support workers", "Service and sales workers" as well as "Craft and related workers" as especially affected.

In summary, only A.T. Kearny's study should be directly comparable to our examination in terms of methodology. The studies we discussed in this section all agree that computerization will have an impact on occupations and the future labor market structure. Interestingly, while many of the above described studies expect Industry 4.0 to have a considerable impact on the labor market the recent policy brief by the Austrian Federal Ministry of Science, Research and Economy (BMWFW) points out that the recent process of digitization in our society is only at first sight a revolutionizing development, while on closer inspection it is rather a continuation of already existing processes from the past (Schwarzbauer 2017). As an example, the author states the internationalization of supply chains which showed tendencies for automation already in the 1990s. Given the successful integration of the Austrian economy in international value chains of production, the significant industrial base, the good access to new technologies and the comparatively lower share of share of routine tasks, Schwarzbauer (2017) argues that Austria has a good base for coping with digital change.

7 Summary and conclusions

The purpose of our study is to examine the impact of Industry 4.0 on the Austrian labor market. We replicate Frey and Osborne's (2017)[6] landmark study for jobs in the US. According to their results, 47% of the US workforce is exposed to a high risk of computerization. Many studies followed, that either translated the results

[6] The work Frey and Osborne (2017) was already published in 2013 as a working paper. Inspired by this working paper, a series of similar works were created for other countries after 2013.

obtained by Frey and Osborne (2017) into other countries (e.g. Pajarinen et al. 2015), or estimated computerization probabilities using a task-based approach (e.g. Bonin et al. 2015). In our study, we wanted to identify areas as well as specific occupations in Austria that affected by computerization, while using a clean methodology. Moreover, we decided to carry out a gender-specific examination in order to test if there are inequalities regarding the risk of automation in Austria. Since only the occupation-based approach can provide us with results for occupations on the most detailed aggregation level, we decided to go with this approach. To ensure a clear allocation process, we used the same crosswalks as used by Frey and Osborne (2014) to map their results to jobs in the UK (Frey and Osborne 2017).

We were able to get results for nearly every relevant Austrian occupation (labor market coverage greater than 93%) on the highest possible aggregation level. In order to prevent misinterpretations, we developed a new, more lenient definition to interpret our results and create a realistic automation scenario for jobs in Austria. Since future Industry 4.0 scenarios seem to depend on various factors, we find it important to provide a sober tool to estimate the impact of Industry 4.0 on jobs in Austria, based on the computerization probabilities by Frey and Osborne (2017). According to our definition, occupations that have a high risk of computerization are very likely to undergo substantial changes regarding the task profile, working hours, skill and education requirements as well as their working environment in general. Since we cannot rule out the complete automation of high-risk occupations, we suggest that only in the worst case, some occupations may be subject to complete automation.

The identification of problem areas, single affected occupations and our gender-specific examination in combination with the basis we built for a more sober interpretation of computerization probabilities are the core contributions of our paper. Another very important aspect of our study is, that it provides results for nearly every relevant Austrian occupation, which corresponds to over 93% of the Austrian labor market.

Our examination shows, that approximately 40% of the Austrian labor force works in occupations that are very likely to undergo substantial changes due to computerization in the future. This result points out the urgent need of vocational education and training in Austria.

We further show that compared to men, a higher proportion of Austrian women work in occupations that are highly susceptible to computerization. This means according to our definition, that women will be more likely affected by substantial technological changes at their workplace in the future.

Our findings are in line with the EBRD (2018) with regard to socio-economic consequences and socio-economic inequalities. Automation has both reduced demand for routine cognitive tasks, thus the total employment share of medium-skilled occupations has been declining while those of both low and high-skilled occupations that are harder to automate have been rising. The level of this job polarization differs across countries according to their sectoral orientation. For example, the use of industrial robots is strongest in manufacturing (particularly in the automotive sector). As these are strongholds of the Austrian economy, large parts of the Austrian labor are subject to change due to digitalization. This change can imply both risk and opportunity and will be a test for adaptive capacities. To successfully manage this technology change, timely and adequate efforts both on the individual and the political level are necessary.

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