



Robots at work

A report on automatable and non-automatable
employment shares in Europe

Written by Dr Grace Lordan
London School of Economics and Political Science
January – 2018



*Social
Europe*

EUROPEAN COMMISSION

Directorate-General for Employment, Social Affairs and Inclusion
Directorate A — Employment and Social Governance
Unit A.4 — Thematic Analysis

Contact: Katarina Jaksic

E-mail: EMPL-A4-UNIT@ec.europa.eu

*European Commission
B-1049 Brussels*

Robots at work

A report on automatable and non-automatable
employment shares in Europe

***Europe Direct is a service to help you find answers
to your questions about the European Union.***

Freephone number (*):

00 800 6 7 8 9 10 11

(* The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (<http://www.europa.eu>).

Luxembourg: Publications Office of the European Union, 2018

ISBN: 978-92-79-80236-2
doi: 10.2767/821645

© European Union, 2018
Reproduction is authorised provided the source is acknowledged.

Table of Contents

OVERVIEW 6
 Headline Points..... 6
METHODS: CLASSIFICATION OF AUTOMATABLE JOBS 7
 Definition 1 7
 Definition 2 8
 Methods 10
OVERVIEW OF THE ANALYSIS 12

OVERVIEW

This work documents the shares of non-automatable and automatable jobs in 24 European countries over the last three decades. Knowledge of this distribution is important as it reveals the countries, and the demographics within these countries whose employment is the most vulnerable to disappearing because of automation, as well countries who have tended towards substituting labour with automation at a faster rate over the last two decades. The same distribution also reveals the jobs that are likely to stay with us in the future, to the extent that they are non-automatable. This information has an obvious place in any public policy debate.

We consider two definitions of automatable work. The first captures jobs that were automatable in the last three decades. This is a great measure of automation retrospectively. The second captures the jobs that are recently automatable (so captures the most recent advances in technology and allows us to consider the shares of jobs that will be automatable over the next ten years). Our analysis gives an overview of differences in the shares of retrospectively and recently automatable jobs across the EC countries included in our analysis.

Headline Points

The headline points are:

- Many more jobs can now be automated, and the shares of these recently automatable jobs vary greatly from country to country. The higher these shares the more vulnerable jobs are in a particular country to disappearing in the next decade. The estimates in this report range from 37% of the total jobs being recently automatable for Norway, to 69% for the Czech Republic (see Table 3 for estimates specific to each country).
- The analysis further divides recently automatable shares into jobs that are fully automatable and polarized automatable (see Table 1 for the categorisation of each individual occupation). The former describes jobs that we expect to be fully substituted by technology in the next decade. These shares range from 21% (Ireland) to 45% (Italy). That is, in Ireland 1 in 5 of the jobs currently held are recently fully automatable. Jobs that are recently fully automatable include vehicle drivers, packers and bank tellers.
- Recently polarized automatable shares relate to jobs where technology is now available which is expected to take on some aspects of a job but not others over the next decade. Examples of recently polarized automatable jobs include lawyers,

sales demonstrators and library assistants. Over time, it is expected that the shares of these jobs will decrease but the occupation itself will not disappear. 35% of occupations in Belgium are estimated to be recently polarized automatable, comparing to 13% in Norway. Estimates for the 24 countries in this analysis are provided in Table 3.

- The occupations that still remain non-automatable require either deep thinking or high levels of interpersonal skills. We do not expect these shares to decrease in the next decade.
- Our country level analysis supports the premise that the technology coming on stream now allows for large shares of jobs with 'low' people to be automated. In contrast, lesser shares of jobs with 'high' people content are potentially automatable with recent technological advances.
- Our country level analysis reveals that recent automation is not divisive along demographic lines (like age and gender) when it comes to substituting for jobs. Rather, the largest shares of jobs that can be potentially lost belong to low skill individuals who do low income jobs. So, the greatest losers in the advent of technology are likely to be low skilled individuals who currently earn a low wage.
- Future research needs to consider what at the country level explains the shares of recently automatable, fully automatable and polarized automatable jobs. This information is invaluable for policy makers as they make decisions on the extent and exactly how they will intervene in the diffusion of technology which can substitute workers.

METHODS: CLASSIFICATION OF AUTOMATABLE JOBS

Definition 1

To achieve our goal the report considers two definitions which capture whether or not a job is automatable. Both definitions are available at the three-digit occupation code level. The first definition that we consider is owed to Autor and Dorn (2013) and Autor et al. (2015) with routine task intensity in each three-digit occupation defined as:

$$RTI_k = \ln(T_k^R) - \ln(T_k^M) - \ln(T_k^A) \quad (1)$$

In equation 1 T_k^R , T_k^M , and T_k^A are the levels of routine, manual, and abstract task inputs

for occupation k measured at the 3-digit occupation code level. Thus, Equation (1) is increasing in the absolute and relative quantity of tasks that are automatable within occupation k . The levels of each of these variables are defined using variables from versions of the *Dictionary of Occupation Titles*, where incumbents are asked to grade the level of their occupation with respect to particular attributes. Routine tasks involve a predictable sequence of actions which are easily codifiable. Therefore, it is already possible to have these tasks carried out by technology as well as humans. Conversely, manual tasks require actions that are not generally predictable, so substitution with technology has so far been limited. Abstract tasks then require high-level thinking that is complementary with technology (Autor, 2013). So, a job will have high levels of routine task intensity if it has high levels of routine tasks, and low levels of manual and abstract tasks. An occupation is then defined as automatable if it is in the top tertile of this distribution. This definition is a great measure for thinking about the automation of work retrospectively.

Definition 2

The second definition is owed to Lordan and Josten (2017). Lordan and Josten (2017) take the occupations classified by Autor and Dorn (2013) as given, but also reclassify additional occupations as automatable to take into account the seismic change on the horizon with respect to jobs that will be automated in the future. Therefore this definition allows us to provide estimates of the shares of jobs within countries that could be automated within the next decade. These are jobs where the technology is now becoming available to allow for automation, but the jobs are not currently labelled as 'automatable' by Autor and Dorn (2013). These jobs are recently automatable. For example, face-to face- service occupations are classified as non-automatable by Autor and Dorn (2013), however, already there is a hotel in Tokyo that is staffed by robots¹ and a restaurant in Germany that relies on a robot chef². We note that decision to take up this automation will differ from country to country depending on their wage structure, level of unionisation and local labour supply, among other things. This underlines the importance of considering definition 2. That is, it allows policy makers to consider how they will handle the automation of employment going forward, and whether they will allow technology to diffuse at its own rate, or if they will intervene³.

Autor and Dorn (2013) define the first tertile of equation 1 as automatable. Given that there are 323 occupation codes, this implies that there 201 codes classified as non-

¹ Multi-lingual robots provide the receptionists duties, a robotic arm tends to the luggage room and porter robots carry luggage to room. Lost keys are not an issue as rooms respond to face recognition software.

² Huis Ten Bosch: Here robots prepare food, with one robot being in charge of making pancakes, it mixes batter, and uses robotic arms to flip the pancakes before dressing them.

³ For instance, a newly automatable job with large shares is vehicle driver. In many countries the law currently requires a person to be in a vehicle. By construction this law serves to slow down job loss associated with driverless technologies.

automatable. In order to decide on whether an occupation in this subset is recently automatable Lordan and Josten (2017) explore patent data. They argue that a significant amount of promising research and development that is searching for a substitute for a particular job, defined as having filed a relevant patent, signals that this job is highly likely to be automatable in the next decade. To determine the level of patent activity they rely on Google Patents⁴. For the remaining 3-digit occupations labelled as non-automatable according to Autor and Dorn (2013), Lordan and Josten (2017) search Google Patents to determine if a technology is actively being developed as a substitute for that occupation. Specifically, they search for variants of the occupation name, plus either of the terms 'robot', 'automation' or "artificial intelligence". For example, for registered nurses they search for 'nurse' and 'robot' or 'automation' or "artificial intelligence". In this case they find one patent. For truck-driver they search for 'truck' and 'driverless' or 'robot' or 'automation' or "artificial intelligence." In this case they find many patents. Finally, for waiter they search for 'waiter' and robot' or 'automation' or "artificial intelligence." Here they find five patents⁵.

Based on their review Lordan and Josten classify each three-digit occupation into one of the following categories: i) non-automatable; ii) polarized automatable; or iii) fully automatable. The first are jobs where inter personal skills are required in order to gauge the specific tasks that are needed and are unlikely to be automated. Nursing is an example in this category. The second are jobs where there is a lot of R&D which require interpersonal interaction but there is a predictable sequence of events. Here, technology has had some success, with some examples of promising patents that are likely to be successful. However, Lordan and Josten (2017) suggest that developments will progress to a polarization, with human employees being kept in establishments where a personal interaction still holds value and robots being utilized where it does not, at least for the next couple of decades. An example here is wait staff where robots may have had some success substituting humans in low cost or quirky establishments where the level of service required is minimal, but are unlikely to displace waiters offering a fine dining experience where the interactions expected with customers are less predictable. Another is lawyers, where machines can substitute for a previous need to synthesis large volumes of text from books of law but cannot substitute for the abstract thinking evidenced in top barristers during serious trials. Last are the jobs where there is recently a lot of successful R&D and people may care less about whether the job is done by a robot or a human. So, the added value to the customer of having a human carry out these roles is zero. Here, there have

⁴ Specifically, Google patents covers over 87 million patent publications from the following patent offices: United States, Europe, Japan, China, South Korea, WIPO, Russia, Germany, United Kingdom, Canada, France, Spain, Belgium, Germany, Finland, Luxembourg and the Netherlands. Patents that are non-English have been translated by Google patents and indexed.

⁵ A documentation of this review can be found in the appendix of Josten and Lordan (2017).

been significant developments to the extent where Lordan and Josten (2017) predict a cull of jobs in the next decade. An example here is truck drivers⁶.

Table 1 documents each three-digit occupation and their associated classification according to Autor and Dorn (2013) and Lordan and Josten (2017). A reader can think of the Lordan and Josten (2017) classification as 'recently automatable' – that is, recently technology has become available which allows for the automation of this occupation, with an expectation that this automation over the next decade will erode the occupation's shares in the absence of policy intervention.

Occupations classified as automatable under the two definitions include accountants, air traffic controllers, typists, and bank tellers. Those classified as non-automatable under the two definitions include: aerospace engineers, mathematicians, nurses, teachers, economists, psychologists and hairdressers. These are the jobs that will not be affected by technology in the coming decades. Notably these occupations centre around two main characteristics deep thinking and/or interactions with people. Jobs that are recently polarized automatable according to Lordan and Josten (2017) are speech therapists, librarians, teacher's aides, wait staff and masons. In general, these are jobs where there is heterogeneity in the tasks complexity with requirements at the low end of complexity being automatable, and those at the high end being non-automatable. Jobs that are recently fully automatable according to Lordan and Josten (2017) are vehicle drivers of all kinds, packers, power plant operators and mail carriers. Notably, the Lordan and Josten (2017) classification suggests that automation will hollow out occupations that are mid and low skill to a far greater extent than those at the top of the skill distribution in the next decade.

Methods

Our overall aim is to provide information on which European countries have the highest shares of occupations classified as automatable by Autor and Dorn (2013), and classified as recently fully automatable and recently polarized automatable by Lordan and Josten (2017). We calculate these shares for three decades, the 90's, 00's and 10's for Autor and Dorn (2013) to get an idea of whether some countries have adopted automation at a faster rate than others retrospectively. For Lordan and Josten (2017) we focus on the 10's period only when calculating recently automatable shares.

To calculate the shares, we calculate the total number of jobs that are automatable in each country for a specific time period (the 90's, 00's or 10's), the denominator is then equal

⁶ We note that Lordan and Josten (2017) also consider another stricter definition of automatable employment which looks to see if the jobs classified as automatable under definition 2 have a successful pilot or trial already in industry. This definition has a correlation of 0.88 with definition 2 so we are not worried about significant finding differences across these classifications.

to the total number of jobs in the same time period. We draw on the EU LFS, and in general rely on data from 1993-1996, 2003-2006 and 2013 – 2016. We choose these time periods to avoid having periods of recession in our calculations⁷. We include 24 countries in our analysis. Unfortunately, three-digit occupation codes are not available in the 1980s so we may not see trends in diffusion of information technology over this period⁸, however countries that have had a period of diffusion in the 80's will have relatively low and flat shares of Autor and Dorn (2013) automatable employment in the 90's, which we will see in the analysis.

We next extend our country level analysis, to provide for each country a more nuanced description of their shares of automatable employment. Specifically, for each country we present figures that document the shares of automatable jobs across countries according to both definitions. We also do these calculations by specific strata. The numerator is then the share of automatable employment in a country, strata and time period, and the denominator is total employment in a country, strata and time period.

We focus on the following strata:

- 1) high skill, mid skill and low skill jobs
- 2) high compensation and low compensation jobs
- 3) high in 'people' and low in 'people' jobs
- 4) older, middle aged and young workers
- 5) male and female workers

So, for example when we calculate the high skill shares, the numerator is the share of automatable employment in a country that relates to high skill workers and a specific time period.

Data

Our main data source is the EU-LFS data. These data are matched to the Autor and Dorn (2013) 3-digit occupation definition of automatable jobs by cross walks provided by Lordan and Pischke (2017)⁹. Age and gender strata are determined from within the EU –LFS data.

⁷ For a small number of countries we need to use different years in calculating the 90's shares. This is noted in the country level description of the results. A few countries had to be excluded from the analysis owing to a lack of data (we require at least two-time points and three-digit occupation codes. These are Bulgaria, Switzerland, Malta, Poland and Romania.

⁸ 1980's was notable period of diffusion for information technology. Nordhaus (2007) show that overall after a slow-down in the progress of computing adoption in the 1960s and 1970 (owing to a slow in annual price declines), an acceleration followed in the 1980's onwards when larger price declines ensued.

⁹ In the EU LFS we first cross walk ISCO 2010 to ISCO 88. Next we crosswalk ISCO 88 to the three-digit occupation codes. Details of occupations that correspond to these codes can be found in Table 1.

Classifications of three-digit occupation codes into high and low people content are consistent with definitions provided by Lordan and Pischke (2016)¹⁰. Considering whether there is a bifurcation by people content adds value as it is informative of the value of interpersonal (no cognitive) skills in the years going forward which are currently not taught in an official capacity on education curriculum. High and low-income jobs are determined by classifications from the ONET database¹¹, given that the income data in the EU LFS is not available. Finally, high, mid and low skilled jobs are classified based on information on the required education, experience and training (both on and off site) for each three-digit occupation code¹².

OVERVIEW OF THE ANALYSIS

Table 2 documents the Autor and Dorn (2013) (AD) shares of automatable employment over three decades (90's, 00's and 10's). For Germany, Italy, Czech Republic, France, Sweden, Austria, UK, Spain, Estonia, Lithuania, Greece and Croatia we do not see any significant evidence of continued automation over the three decades. However, for Hungary, Netherlands, Slovakia, Portugal, Denmark, Finland, Cyprus, Norway, Iceland, Luxemburg, Ireland and Belgium we do see evidence of shares of AD automatable employment decreasing over the three decades. Notably, even in the 10's there is a large variation in the AD shares of automatable employment across countries. This suggests that some countries with higher AD automatable shares (like Germany, Italy and the Netherlands who have shares of almost 40%) have for one reason or another not adopted technology or re organised work to the extent of other countries in the EC (like Ireland and Belgium who have AD shares of less than 20%).

Table 3 calculates the shares of recently automatable employment using the definition put forward by Lordan and Josten (2017) (LJ). This captures the jobs that are now automatable given the technologies recently available. There is great variation across the 24 countries, with Ireland and Norway having the lowest shares of LJ recently automatable jobs. Still, even in these countries the estimates suggest that 38 out of 100 jobs currently available are automatable. For the UK this number is 43 out of 100. The estimates suggest that the Czech Republic and Germany have the highest shares of LJ recently automatable jobs. For

¹⁰ Lordan and Pischke (2016) create three latent factors based on the 79 context and activities ONET variables. They follow the psychometric literature and use exploratory factor analysis to reduce the dimensionality first (Gorsuch, 1983; Thompson, 2004). They follow Heckman et al. (2012) and extract three latent variables that they label 'people,' 'brains,' and 'brawn'. The 'people' variable relates to jobs that have a significant amount of engagement with third parties in some way or other.

¹¹ Specifically, ONET has a variable in its values database which is on a scale of 1 – 7 that denotes how high compensation is for each three-digit occupation code. We classify occupations as high compensation if they are in the top tertile of this variable. Conversely occupations are denoted as low compensation if they are in the bottom tertile.

¹² We draw on information from the ONET database which defines the levels required for education, experience, on site and off-site training. We combine these variables using an exploratory factor analysis. The tertiles of the final variable then define our low, mid and low skill classifications.

Germany the estimates suggest that 66 out of 100 jobs are currently automatable. For the Czech Republic this number is 69 out of 100.

We further divide the LJ shares into jobs that are recently fully automatable and recently polarized automatable (see Table 1 for the categorisation of each individual occupation). By construction the sum of recently fully automatable and recently polarized optimal is equal to recently automatable jobs as defined by LJ. Recently fully automatable are jobs that can now – or soon - be fully substituted by technology. From Table 3, these shares range from 21% (Ireland) to 45% (Italy). That is, in Ireland 1 in 5 of the jobs currently held are recently fully automatable. For Italy this number is close to 1 in 2.

Recently polarized automatable shares relate to jobs where technology is now available which will be able to take on some aspects of a job but not others. Examples of recently polarized automatable jobs include lawyers, sales demonstrators and library assistants. Over time, it is expected that the shares of these jobs will decrease but the occupation itself will not disappear. 35% of occupations in Belgium are estimated to be polarized automatable, comparing to 13% in Norway.

Overall Table 3 suggests that all countries in the EC hold enough recently automatable jobs that we can be certain that technology can shape the nature and number of jobs available to a significant extent. The extent of this shaping will depend on local labour markets and their laws, as well as the countries own characteristics and political landscape. Future research should consider exactly which factors help explain the shares of automatable employment in Table 2 and 3. It is crucial that these linkages are understood so as to inform policy makers on their potential policy.

Table 1: Occupations Classified by Autor and Dorn (2013) and Lordan and Josten (2017)

Occupation	Autor and Dorn	Lordan and Josten
Chief executives, public administrators, and legislators	Non-Automatable	Non- Automatable
Financial managers	Automatable	Automatable
Human resources and labour relations managers	Non-Automatable	Polarized
Managers and specialists in marketing, advert., PR	Non-Automatable	Automatable
Managers in education and related fields	Non-Automatable	Non- Automatable
Managers of medicine and health occupations	Non-Automatable	Non- Automatable
Managers of properties and real estate	Non-Automatable	Non- Automatable
Funeral directors	Automatable	Fully Automatable
Managers and administrators, n.e.c.	Non-Automatable	Non- Automatable
Accountants and auditors	Automatable	Fully Automatable
Insurance underwriters	Automatable	Fully Automatable
Other financial specialists	Automatable	Fully Automatable
Management analysts	Non-Automatable	Non- Automatable

Occupation	Autor and Dorn	Lordan and Josten
Personnel, HR, training, and labour rel. specialists	Non-Automatable	Polarized Automatable
Purchasing agents and buyers of farm products	Automatable	Fully Automatable
Buyers, wholesale and retail trade	Non-Automatable	Non- Automatable
Purchasing managers, agents, and buyers, n.e.c.	Non-Automatable	Non- Automatable
Business and promotion agents	Non-Automatable	Non- Automatable
Construction inspectors	Non-Automatable	Non- Automatable
Inspectors and compliance officers, outside	Non-Automatable	Non- Automatable Polarized
Management support occupations	Non-Automatable	Automatable
Architects	Automatable	Non- Automatable
Aerospace engineers	Non-Automatable	Non- Automatable
Metallurgical and materials engineers	Non-Automatable	Non- Automatable
Petroleum, mining, and geological engineers	Non-Automatable	Non- Automatable
Chemical engineers	Non-Automatable	Non- Automatable
Civil engineers	Non-Automatable	Non- Automatable
Electrical engineers	Non-Automatable	Non- Automatable
Industrial engineers	Non-Automatable	Non- Automatable
Mechanical engineers	Non-Automatable	Non- Automatable
Engineers and other professionals, n.e.c.	Non-Automatable	Non- Automatable
Computer systems analysts and computer scientists	Non-Automatable	Non- Automatable
Operations and systems researchers and analysts	Non-Automatable	Non- Automatable
Actuaries	Automatable	Fully Automatable
Mathematicians and statisticians	Non-Automatable	Non- Automatable
Physicists and astronomers	Non-Automatable	Non- Automatable
Chemists	Non-Automatable	Non- Automatable
Atmospheric and space scientists	Automatable	Non- Automatable
Geologists	Non-Automatable	Non- Automatable
Physical scientists, n.e.c.	Automatable	Fully Automatable
Agricultural and food scientists	Non-Automatable	Non- Automatable
Biological scientists	Non-Automatable	Non- Automatable
Foresters and conservation scientists	Non-Automatable	Non- Automatable
Medical scientists	Non-Automatable	Non- Automatable
Physicians	Non-Automatable	Non- Automatable
Dentists	Non-Automatable	Non- Automatable
Veterinarians	Automatable	Non- Automatable
Optometrists	Automatable	Polarized Automatable
Podiatrists	Non-Automatable	Non- Automatable
Other health and therapy occupations	Non-Automatable	Non- Automatable
Registered nurses	Non-Automatable	Non- Automatable Polarized
Pharmacists	Automatable	Automatable
Dieticians and nutritionists	Automatable	Fully Automatable
Respiratory therapists	Non-Automatable	Non- Automatable
Occupational therapists	Non-Automatable	Non- Automatable
Physical therapists	Non-Automatable	Non- Automatable Polarized
Speech therapists	Non-Automatable	Automatable
Therapists, n.e.c.	Non-Automatable	Non- Automatable Polarized
Physicians' assistants	Non-Automatable	Automatable
Subject instructors, college	Non-Automatable	Non- Automatable

Occupation	Autoren und Dorn	Lordan and Josten
Kindergarten and earlier school teachers	Non-Automatable	Non- Automatable
Primary school teachers	Non-Automatable	Non- Automatable
Secondary school teachers	Non-Automatable	Non- Automatable
Special education teachers	Non-Automatable	Non- Automatable
Teachers, n.e.c.	Non-Automatable	Non- Automatable
Vocational and educational counselors	Non-Automatable	Non- Automatable
		Polarized
Librarians	Non-Automatable	Automatable
Archivists and curators	Non-Automatable	Non- Automatable
Economists, market and survey researchers	Non-Automatable	Non- Automatable
Psychologists	Non-Automatable	Non- Automatable
Social scientists and sociologists, n.e.c.	Non-Automatable	Non- Automatable
Urban and regional planners	Automatable	Non- Automatable
Social workers	Non-Automatable	Non- Automatable
Clergy and religious workers	Non-Automatable	Non- Automatable
Welfare service workers	Non-Automatable	Non- Automatable
		Polarized
Lawyers and judges	Automatable	Automatable
Writers and authors	Automatable	Non- Automatable
Technical writers	Non-Automatable	Non- Automatable
Designers	Non-Automatable	Non- Automatable
Musicians and composers	Non-Automatable	Non- Automatable
Actors, directors, and producers	Non-Automatable	Non- Automatable
Painters, sculptors, craft-artists, and print-makers	Automatable	Fully Automatable
Photographers	Automatable	Fully Automatable
Dancers	Non-Automatable	Non- Automatable
Art/entertainment performers and related occs	Non-Automatable	Non- Automatable
Editors and reporters	Automatable	Non- Automatable
Announcers	Automatable	Non- Automatable
		Polarized
Athletes, sports instructors, and officials	Non-Automatable	Automatable
Clinical laboratory technologies and technicians	Non-Automatable	Fully Automatable
Dental hygienists	Automatable	Fully Automatable
Health record technologists and technicians	Automatable	Fully Automatable
Radiologic technologists and technicians	Non-Automatable	Fully Automatable
Licensed practical nurses	Non-Automatable	Non- Automatable
		Polarized
Health technologists and technicians, n.e.c.	Non-Automatable	Automatable
Engineering technicians	Non-Automatable	Non- Automatable
Drafters	Automatable	Fully Automatable
Surveyors, cartographers, mapping scientists/techs	Non-Automatable	Polarized
		Automatable
		Polarized
Biological technicians	Non-Automatable	Automatable
		Polarized
Chemical technicians	Non-Automatable	Automatable
		Polarized
Other science technicians	Non-Automatable	Automatable
		Polarized
Airplane pilots and navigators	Non-Automatable	Automatable
Air traffic controllers	Automatable	Fully Automatable
		Polarized
Broadcast equipment operators	Non-Automatable	Automatable
Computer software developers	Non-Automatable	Non- Automatable

Occupation	Autor and Dorn	Lordan and Josten
Programmers of numerically controlled machine tools	Non-Automatable	Non- Automatable
Legal assistants and paralegals	Automatable	Fully Automatable
Technicians, n.e.c.	Non-Automatable	Polarized
Sales supervisors and proprietors	Non-Automatable	Automatable
Insurance sales occupations	Non-Automatable	Non- Automatable
Real estate sales occupations	Automatable	Fully Automatable
Financial service sales occupations	Automatable	Fully Automatable
Advertising and related sales jobs	Automatable	Fully Automatable
Sales engineers	Automatable	Fully Automatable
Salespersons, n.e.c.	Non-Automatable	Non- Automatable
Retail salespersons and sales clerks	Non-Automatable	Non- Automatable
Cashiers	Automatable	Fully Automatable
Door-to-door sales, street sales, and news vendors	Non-Automatable	Non- Automatable
Sales demonstrators, promoters, and models	Non-Automatable	Polarized
Office supervisors	Non-Automatable	Automatable
Computer and peripheral equipment operators	Automatable	Fully Automatable
Secretaries and stenographers	Non-Automatable	Non- Automatable
Typists	Automatable	Fully Automatable
Interviewers, enumerators, and surveyors	Automatable	Fully Automatable
Hotel clerks	Automatable	Non- Automatable
Transportation ticket and reservation agents	Automatable	Fully Automatable
Receptionists and other information clerks	Automatable	Fully Automatable
Correspondence and order clerks	Automatable	Fully Automatable
Human resources clerks, excl payroll and timekeeping	Automatable	Fully Automatable
Library assistants	Automatable	Polarized
File clerks	Non-Automatable	Automatable
Records clerks	Automatable	Fully Automatable
Bookkeepers and accounting and auditing clerks	Automatable	Fully Automatable
Payroll and timekeeping clerks	Automatable	Fully Automatable
Billing clerks and related financial records processing	Automatable	Fully Automatable
Mail and paper handlers	Automatable	Fully Automatable
Office machine operators, n.e.c.	Automatable	Fully Automatable
Telephone operators	Automatable	Fully Automatable
Other telecom operators	Automatable	Fully Automatable
Postal clerks, excluding mail carriers	Automatable	Fully Automatable
Mail carriers for postal service	Automatable	Fully Automatable
Mail clerks, outside of post office	Non-Automatable	Fully Automatable
Messengers	Automatable	Fully Automatable
Dispatchers	Automatable	Fully Automatable
Shipping and receiving clerks	Automatable	Fully Automatable
Stock and inventory clerks	Automatable	Fully Automatable
Meter readers	Automatable	Fully Automatable
Weighers, measurers, and checkers	Automatable	Fully Automatable
Material recording, sched., prod., plan., expediting cl.	Automatable	Fully Automatable
Insurance adjusters, examiners, and investigators	Automatable	Fully Automatable
Customer service reps, invest., adjusters, excl. insur.	Automatable	Fully Automatable

Occupation	Autor and Dorn	Lordan and Josten
Eligibility clerks for government prog., social welfare	Automatable	Fully Automatable
Bill and account collectors	Automatable	Fully Automatable
General office clerks	Automatable	Fully Automatable
Bank tellers	Automatable	Fully Automatable
Proofreaders	Automatable	Fully Automatable
Data entry keyers	Automatable	Fully Automatable
Statistical clerks	Automatable	Fully Automatable
		Polarized
Teacher's aides	Non-Automatable	Automatable
Administrative support jobs, n.e.c.	Automatable	Fully Automatable
		Polarized
Housekeepers, maids, butlers, and cleaners	Non-Automatable	Automatable
Laundry and dry cleaning workers	Automatable	Fully Automatable
Supervisors of guards	Non-Automatable	Non- Automatable
Fire fighting, fire prevention, and fire inspection occs	Non-Automatable	Polarized
		Automatable
Police and detectives, public service	Non-Automatable	Non- Automatable
Sheriffs, bailiffs, correctional institution officers	Non-Automatable	Non- Automatable
Crossing guards	Non-Automatable	Non- Automatable
Guards and police, except public service	Automatable	Fully Automatable
		Polarized
Protective service, n.e.c.	Non-Automatable	Automatable
Supervisors of food preparation and service	Non-Automatable	Non- Automatable
		Polarized
Bartenders	Automatable	Automatable
		Polarized
Waiters and waitresses	Non-Automatable	Automatable
Cooks	Automatable	Fully Automatable
		Polarized
Food preparation workers	Non-Automatable	Automatable
Miscellaneous food preparation and service workers	Non-Automatable	Polarized
		Automatable
Dental Assistants	Automatable	Fully Automatable
Health and nursing aides	Non-Automatable	Non- Automatable
Supervisors of cleaning and building service	Non-Automatable	Non- Automatable
Superv. of landscaping, lawn service, groundskeeping	Non-Automatable	Polarized
		Automatable
		Polarized
Gardeners and groundskeepers	Non-Automatable	Automatable
		Polarized
Janitors	Non-Automatable	Automatable
Pest control occupations	Non-Automatable	Fully Automatable
Barbers	Automatable	Non- Automatable
Hairdressers and cosmetologists	Automatable	Non- Automatable
		Polarized
Recreation facility attendants	Non-Automatable	Automatable
		Polarized
Guides	Non-Automatable	Automatable
		Polarized
Ushers	Non-Automatable	Automatable
		Polarized
Baggage porters, bellhops and concierges	Non-Automatable	Automatable
		Polarized
Recreation and fitness workers	Non-Automatable	Automatable

Occupation	Auto and Dorn	Lordan and Josten
Motion picture projectionists	Automatable	Fully Automatable
Child care workers	Non-Automatable	Non- Automatable
Personal service occupations, n.e.c	Non-Automatable	Polarized
Supervisors of personal service jobs, n.e.c	Non-Automatable	Automatable
Public transportation attendants and inspectors	Non-Automatable	Polarized
Animal caretakers, except farm	Non-Automatable	Automatable
Farmers (owners and tenants)	<i>Automatable</i>	Non- Automatable
Farm managers	<i>Automatable</i>	Fully Automatable
Farm workers, incl. nursery farming	<i>Automatable</i>	Fully Automatable
Graders and sorters of agricultural products	<i>Automatable</i>	Fully Automatable
Inspectors of agricultural products	<i>Automatable</i>	Fully Automatable
Timber, logging, and forestry workers	<i>Automatable</i>	Fully Automatable
Fishers, marine life cultivators, hunters, and kindred	<i>Automatable</i>	Fully Automatable
Supervisors of mechanics and repairers	Non-Automatable	Fully Automatable
Automobile mechanics and repairers	Non-Automatable	Non- Automatable
Bus, truck, and stationary engine mechanics	Non-Automatable	Non- Automatable
Aircraft mechanics	Non-Automatable	Non- Automatable
Small engine repairers	Non-Automatable	Non- Automatable
Auto body repairers	Automatable	Non- Automatable
Heavy equipment and farm equipment mechanics	Automatable	Fully Automatable
Industrial machinery repairers	Non-Automatable	Non- Automatable
Machinery maintenance occupations	Non-Automatable	Non- Automatable
Repairers of industrial electrical equipment	Automatable	Fully Automatable
Repairers of data processing equipment	Automatable	Fully Automatable
Repairers of household appliances and power tools	Automatable	Fully Automatable
Telecom and line installers and repairers	Non-Automatable	Non- Automatable
Repairers of electrical equipment, n.e.c.	Non-Automatable	Non- Automatable
Heating, air conditioning, and refrigeration mechanics	Non-Automatable	Non- Automatable
Precision makers, repairers, and smiths	Automatable	Non- Automatable
Locksmiths and safe repairers	Automatable	Fully Automatable
Repairers of mechanical controls and valves	Non-Automatable	Polarized
Elevator installers and repairers	Non-Automatable	Automatable
Millwrights	Non-Automatable	Non- Automatable
Mechanics and repairers, n.e.c.	Non-Automatable	Non- Automatable
Supervisors of construction work	Non-Automatable	Non- Automatable
Masons, tilers, and carpet installers	Non-Automatable	Polarized
Carpenters	Non-Automatable	Automatable
Drywall installers	Non-Automatable	Non- Automatable
Electricians	Non-Automatable	Non- Automatable
Electric power installers and repairers	Non-Automatable	Non- Automatable
Painters, construction and maintenance	Non-Automatable	Polarized
Paperhangers	Non-Automatable	Automatable
Plasterers	Non-Automatable	Polarized
Plumbers, pipe fitters, and steamfitters	Non-Automatable	Automatable
	Non-Automatable	Non- Automatable

Occupation	Autor and Dorn	Lordan and Josten
		Polarized
Concrete and cement workers	Non-Automatable	Automatable
Glaziers	Non-Automatable	Non- Automatable
Insulation workers	Non-Automatable	Non- Automatable
Paving, surfacing, and tamping equipment operators	Non-Automatable	Non- Automatable
Roofers and slaters	Non-Automatable	Non- Automatable
Structural metal workers	Non-Automatable	Non- Automatable
Drillers of earth	Non-Automatable	Fully Automatable
		Polarized
Misc. construction and related occupations	Non-Automatable	Automatable
Drillers of oil wells	Non-Automatable	Fully Automatable
		Polarized
Explosives workers	Non-Automatable	Automatable
		Polarized
Miners	Non-Automatable	Automatable
		Polarized
Other mining occupations	Non-Automatable	Automatable
		Polarized
Production supervisors or foremen	Non-Automatable	Automatable
Tool and die makers and die setters	Automatable	Fully Automatable
Machinists	Automatable	Fully Automatable
Boilermakers	Automatable	Fully Automatable
Precision grinders and fitters	Automatable	Fully Automatable
Patternmakers and model makers	Automatable	Fully Automatable
Engravers	Automatable	Fully Automatable
		Polarized
Other metal and plastic workers	Non-Automatable	Automatable
Cabinetmakers and bench carpenters	Non-Automatable	Non- Automatable
Furniture/wood finishers, other prec. wood workers	Automatable	Fully Automatable
		Polarized
Dressmakers, seamstresses, and tailors	Non-Automatable	Automatable
Upholsterers	Automatable	Fully Automatable
Shoemakers, other prec. apparel and fabric workers	Non-Automatable	Fully Automatable
Hand molders and shapers, except jewelers	Automatable	Fully Automatable
Optical goods workers	Automatable	Fully Automatable
Dental laboratory and medical appliance technicians	Non-Automatable	Polarized
		Automatable
Bookbinders	Non-Automatable	Fully Automatable
Other precision and craft workers	Automatable	Fully Automatable
Butchers and meat cutters	Automatable	Fully Automatable
Bakers	Automatable	Fully Automatable
Batch food makers	Automatable	Fully Automatable
		Polarized
Water and sewage treatment plant operators	Non-Automatable	Automatable
Power plant operators	Non-Automatable	Fully Automatable
Plant and system operators, stationary engineers	Non-Automatable	Polarized
		Automatable
		Polarized
Other plant and system operators	Non-Automatable	Automatable
Lathe, milling, and turning machine operatives	Automatable	Fully Automatable
Punching and stamping press operatives	Non-Automatable	Fully Automatable
Rollers, roll hands, and finishers of metal	Non-Automatable	Non- Automatable

Occupation	Auto and Dorn	Lordan and Josten
Drilling and boring machine operators	Automatable	Fully Automatable
Grinding, abrading, buffing, and polishing workers	Automatable	Fully Automatable Polarized
Forge and hammer operators	Non-Automatable	Automatable
Molders and casting machine operators	Automatable	Fully Automatable
Metal platers	Automatable	Fully Automatable Polarized
Heat treating equipment operators	Non-Automatable	Automatable
Sawing machine operators and sawyers	Non-Automatable	Fully Automatable
Nail, tacking, shaping and joining mach ops (wood)	Automatable	Fully Automatable
Other woodworking machine operators	Automatable	Fully Automatable
Printing machine operators, n.e.c.	Automatable	Fully Automatable
Typesetters and compositors	Automatable	Fully Automatable
Winding and twisting textile and apparel operatives	Automatable	Fully Automatable
Knitters, loopers, and toppers textile operatives	Automatable	Fully Automatable
Textile cutting and dyeing machine operators	Automatable	Fully Automatable
Textile sewing machine operators	Non-Automatable	Fully Automatable
Shoemaking machine operators	Non-Automatable	Fully Automatable Polarized
Clothing pressing machine operators	Non-Automatable	Automatable
Miscellaneous textile machine operators	Automatable	Fully Automatable
Cementing and gluing machine operators	Automatable	Fully Automatable
Packers, fillers, and wrappers	Non-Automatable	Fully Automatable
Extruding and forming machine operators	Automatable	Fully Automatable
Mixing and blending machine operators	Automatable	Fully Automatable
Separating, filtering, and clarifying machine operators	Non-Automatable	Non- Automatable
Food roasting and baking machine operators	Automatable	Fully Automatable
Washing, cleaning, and pickling machine operators	Automatable	Fully Automatable
Paper folding machine operators	Automatable	Fully Automatable
Furnance, kiln, and oven operators, apart from food	Non-Automatable	Polarized Automatable
Slicing, cutting, crushing and grinding machine	Automatable	Fully Automatable
Photographic process workers	Automatable	Automatable Polarized
Machine operators, n.e.c.	Non-Automatable	Automatable Polarized
Welders, solderers, and metal cutters	Non-Automatable	Automatable
Assemblers of electrical equipment	Automatable	Fully Automatable Polarized
Painting and decoration occupations	Non-Automatable	Automatable
Production checkers, graders, and sorters in manufacturing	Automatable	Fully Automatable
Supervisors of motor vehicle transportation	Non-Automatable	Non- Automatable
Truck, delivery, and tractor drivers	Non-Automatable	Fully Automatable
Bus drivers	Non-Automatable	Fully Automatable
Taxi cab drivers and chauffeurs	Non-Automatable	Fully Automatable Polarized
Parking lot attendants	Non-Automatable	Automatable
Railroad conductors and yardmasters	Non-Automatable	Non- Automatable Polarized
Locomotive operators: engineers and firemen	Non-Automatable	Automatable

Occupation	Autor and Dorn	Lordan and Josten
Railroad brake, coupler, and switch operators	Non-Automatable	Polarized
Ship crews and marine engineers	Non-Automatable	Automatable
Miscellaneous transportation occupations	Non-Automatable	Non- Automatable
Operating engineers of construction equipment	Non-Automatable	Polarized
Crane, derrick, winch, hoist, longshore operators	Non-Automatable	Automatable
Excavating and loading machine operators	Non-Automatable	Non- Automatable
Stevedores and misc. material moving occupations	Non-Automatable	Polarized
Helpers, constructions	Non-Automatable	Automatable
Helpers, surveyors	Non-Automatable	Polarized
Construction laborers	Non-Automatable	Automatable
Production helpers	Automatable	Fully Automatable
Garbage and recyclable material collectors	Non-Automatable	Fully Automatable
Machine feeders and offbearers	Non-Automatable	Polarized
Garage and service station related occupations	Automatable	Automatable
Vehicle washers and equipment cleaners	Automatable	Fully Automatable
Packers and packagers by hand	Automatable	Fully Automatable
Laborers, freight, stock, and material handlers, n.e.c.	Non-Automatable	Polarized
		Automatable

Table 2: Autor and Dorn (2013) Shares of Automatable Employment over three decades

	10's	00's	90's
Germany	0.397	0.377	0.382
Hungary	0.371	0.338	0.327
Netherlands	0.383	0.311	0.301
Slovakia	0.373	0.337	0.277
Italy	0.371	0.394	0.363
Czech Republic	0.327	0.290	0.305
Portugal	0.322	0.315	0.370
France	0.290	0.214	0.263
Sweden	0.283	0.278	0.289
Denmark	0.280	0.285	0.310
Austria	0.284	0.262	0.234
UK	0.243	0.253	0.267
Spain	0.227	0.235	0.220
Finland	0.225	0.234	0.262
Cyprus	0.220	0.349	
Norway	0.220	0.276	0.261
Estonia	0.216	0.215	0.219
Iceland	0.215	0.234	0.252
Luxemburg	0.213	0.261	0.246
Lithuania	0.207	0.185	0.200
Ireland	0.190	0.302	0.321
Belgium	0.184	0.205	0.215
Greece	0.184	0.189	0.179
Croatia	0.166	0.173	0.161

Note: Table is ordered by Autor and Dorn (2013) share value in the 10's.

**Table 3: Lordan and Josten (2017) shares of automatable employment in the 10's
Notes**

	Recently Automatable	Fully Automatable	Polarized Automatable
Czech Republic	0.692	0.406	0.286
Germany	0.663	0.446	0.217
Cyprus	0.645	0.258	0.387
Portugal	0.644	0.419	0.225
Spain	0.613	0.316	0.296
Hungary	0.606	0.439	0.167
Italy	0.584	0.449	0.135
Lithuania	0.583	0.307	0.276
Slovakia	0.578	0.425	0.153
Austria	0.576	0.335	0.241
Estonia	0.575	0.293	0.282
France	0.575	0.328	0.247
Belgium	0.573	0.223	0.349
Luxembourg	0.568	0.269	0.299
Netherlands	0.567	0.376	0.191
Finland	0.546	0.288	0.258
Iceland	0.539	0.287	0.253
Sweden	0.513	0.289	0.224
Greece	0.494	0.349	0.145
Croatia	0.480	0.247	0.233
Denmark	0.476	0.327	0.149
UK	0.433	0.286	0.147
Ireland	0.379	0.209	0.170
Norway	0.374	0.248	0.126

Note: Table is ordered from highest to lowest according to recently automatable shares of employment values.

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
via EU Bookshop (<http://bookshop.europa.eu>);
- more than one copy or posters/maps:
from the European Union's representations (http://ec.europa.eu/represent_en.htm);
from the delegations in non-EU countries
(http://eeas.europa.eu/delegations/index_en.htm);
by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm)
or calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*). The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (<http://bookshop.europa.eu>).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union
(http://publications.europa.eu/others/agents/index_en.htm).



Publications Office

doi:10.2767/821645