Muistio • Brief

34 • 22 April 2015

ISSN-L 2323-2463, ISSN 2323-2463

ETLA Muistiot tarjoavat ajankohtaista tutkimustietoa polttavista yhteiskunnallisista kysymyksistä.
www.etla.fi » julkaisut » muistiot

ETLA • Elinkeinoelämän tutkimuslaitos

ETLA Briefs provide timely research-based information on pressing societal issues.
www.etla.fi » publications » briefs

ETLA • The Research Institute of the Finnish Economy

Computerization Threatens One-Third of Finnish and Norwegian Employment

Mika Pajarinen is a Researcher at ETLA, The Research Institute of the Finnish Economy (mika.pajarinen@etla.fi).

Petri Rouvinen is a Research Director at ETLA, The Research Institute of the Finnish Economy (petri.rouvinen@etla.fi).

Anders Ekeland is a Senior Advisor at Statistics Norway (anders.ekeland@ssb.no).

This brief is an abbreviated version of a report prepared for a committee assessing the future of primary and secondary education in Norway (https://blogg.regjeringen.no/fremtidensskole/, appointed by the *Norwegian Government* in the Royal Decree of 21 June 2013). It builds on earlier work by Pajarinen and Rouvinen (2014), who acknowledge methodological support of Carl Benedikt Frey and Michael A. Osborne (both at *Univ. of Oxford*), data support of Antti Katainen (*Statistics Finland*), and thank Jenni Frilander (YLE), Martin Kenney (*Univ. of California, Davis*), Vesa Vihriälä (ETLA), and John Zysman (*Univ. of California, Berkeley*) for comments and discussions.

Suggested citation: Pajarinen, Mika, Rouvinen, Petri & Ekeland, Anders (22.4.2015).
"Computerization Threatens One-Third of Finnish and Norwegian Employment".
ETLA Brief No 34. http://pub.etla.fi/ETLA-Muistio-Brief-34.pdf

We find that one-third of both Finnish and Norwegian employment will be highly susceptible to computerization in the next decade or two. Low-wage and low-skill occupations appear to be more threatened. Service and public sector jobs are relatively more sheltered than those in manufacturing and the private sector. Nevertheless, computerization will, to some extent, affect all occupations. There can be considerable difficulties for economies to adjust in the shorter run simply because there may be an overwhelming amount of job destruction and an insufficient amount of job creation. The digital transformation of society itself, however, creates a significant number of new needs, and a good way to respond to these needs is to place major emphasis on giving the workforce appropriate and adaptable competences through education and training.

1. Digital Disruption

Deepening digitalization, or computerization, has induced an ongoing societal transformation that may ultimately prove to be comparable to the first industrial revolution. While some related trajectories have continued for most of the postwar era, the past ten years have been particularly disruptive both for the providers of the underlying solutions and for their adapters. This disruption will have considerable implications for the labor market, especially in high-income countries with well-established "industrial era" institutions. In this report, we consider how digitalization impacts the future of jobs in Finland (building on Pajarinen & Rouvinen, 2014) and Norway in the spirit of earlier work by Frey and Osborne (2013).

The digital disruption is attributable to three interrelated bundles of forces:

First, mankind's ability to *produce*, *store*, *process*, and *transmit* digitally coded information has grown exponentially in the last few decades. The much lauded *Moore's Law* refers to the ability to pack transistors in an integrated circuit ever more densely, and similar "laws" have been ongoing in several other relevant domains (with the notable exception of battery efficiency). The economic outcome of these engineering feats has been that the global volume of data, including the capabilities to exploit it, has roughly doubled every one to two years. One feature of this exponential growth is that initially modest increments eventually become colossal. This can be illustrated with an anecdote in *The Economist* (3 January 2015, http://v.gd/U0h57t): *"According to Benedict Evans of Andreessen Horowitz, the new iPhones sold over the weekend of their release in September 2014 contained 25 times more computing power than the whole world had at its disposal in 1995."*

Second, there are three important phenomena that were virtually unknown to global masses of people just a decade ago: *cloud computing*, *mobile internet*, and *social media*. Kushida, Murray, and Zysman (2015) discuss the manner in which "cloud" transforms computing from a scarce to an abundant resource. They note that abundant, ubiquitous, and cheap ICT resources – brought about by cloud computing and related business dynamics – have the potential to alter competitive dynamics in most industries, including those outside the core sectors. Mobile internet underlies emerging, real-time, and often location-based service solutions such as *Uber*, a controversial but globally expanding taxi service. Even if – in advanced markets – mobile devices and their diffusion have remained, broadly speaking, the same in the last few years, the impact of mobility continues to deepen at a surprising pace even in Nordic countries. For example, in Finland, internet searches via mobile devices roughly doubled in 2014 and quadrupled in 2013. Some see social media as a waste of time, but if, globally, people spend well in excess of one billion hours every day on something (from effectively nil a decade ago), it is bound to be a major societal force. Moreover, even though we continue to proxy social media by *Facebook*, *Twitter*, and perhaps a few others, the phenomenon is expanding more rapidly that what we readily observe. For instance, in certain contexts, *Facebook* and *Twitter* are dwarfed by *WhatsApp*, an online messaging service, although it is not even characterized as part of social media.

Third, the digital revolution, which has so far largely lived "on screens," is starting to mesh with our physical surroundings. *Robotics* is hardly a new phenomenon, but it has recently gained better senses (sensors) and much more intelligence (software algorithms, processing capacity). At the same time, the quality-adjusted price of a robot has plummeted; previously unimaginable robotic lawnmowers and vacuum cleaners are commonplace. A bundle of technologies known as *3D printing* or additive manufacturing holds a promise of turning the world of physical objects into a fully-personalized on-demand infofacturing. With the *internet of things*, or even "of everything" (Evans, 2012), emerges an increasingly complete virtual copy of our physical world, which in turn enables a host a new possibilities.

The above three interrelated bundles of forces have some commonalities. Each is undeniably a major global phenomenon; each has experienced huge changes in the last decade and is rapidly evolving; and they all relate to underlying hardware and software. Yet, they are all just enablers; they only have a social impact if they are embedded in the day-to-day lives of individuals and organizations in such a way that behaviors and structures are adjusted to reflect the possibilities that have opened with technological advancement. Since this complementary non-digital, human-centric investment is quite large, perhaps ten times as large as the needed digital investment (Brynjolfsson & Hitt, 2000), and because people and organizations often take years or even decades to fully adjust, the full impact of the recent tsunami of technological advances will unfold in the next two to three decades (even if one wrongly assumes no further technological advancement).

2. Changes in the Workplace

Autor, Levy, and Murnane (2003) suggest that we should consider *work* in a two-dimensional manner. First, to what extent is it all about "muscle *versus* brain" work (mechanical *versus* cognitive), and second, to what extent are there routines – clear rules to put on the work, – *versus* non-routines – the work, which is not formed as a predetermined pattern. According to these authors, digitalization will lead to the substitution of jobs in cognitive routines, including basic accounting tasks. In 2003, they did not consider digitalization to have a significant impact on, say, the work of a plumber and a number of other service professions described as mechanical non-routine work. Their key conclusion was that digitalization *supplements* non-routine cognitive work. The conclusions were similar in a subsequent study by Autor, Dorn, and Hanson (2013).

However, "big data," and automated analytics related to it, also enables the replacement of human work in non-routine cognitive tasks.

Moreover, robots with better sensors and intelligence are also invading the mechanical non-routine tasks in factories and healthcare.

In fact, Frey and Osborne (2013, p. 23) state that *"... it is largely already technologically possible to automate almost any task, provided that sufficient amounts of data are gathered for pattern recognition."*

As such, the *replacement* of occupations and work is a slightly misleading term in this context. Rather, it is the case that work is *redistributed* so that robots and other machines make the work elements in which they have a competitive advantage, and humans deal with work that is difficult for machines. Notwithstanding, the time saved in relation to work may be employed in altogether new tasks, possibly made conceivable by the very same technological advancement.

3. Matching Technologies to Tasks within Occupations

Our study follows the example of Frey and Osborne (2013) in their quantification of the meaning of computerization and the future of employment.[1] They find that *"… 47 percent of total US employment is in the high risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two"* [2] (p. 38). They also note *"… that computerization will mainly substitute for low-skill and low-wage jobs in the near future"* (p. 42). In this report, we provide corresponding estimates for Finland and Norway.

Frey and Osborne match current and forthcoming technologies to tasks within occupations. While the term employed is **computerization**, they consider a broad set of technologies falling under *machine learning*,[3] *mobile robotics*, and *task restructuring* (the exercise is mostly about predicting how already existing technologies might diffuse). The novelty of their analysis is in relating technical possibilities with job tasks and then deriving a *probability of computerization* measure for each occupation. The authors assume a technological capabilities point of view, *i.e.*, they do not consider political or social forces that may influence technology adoption. Typically, these forces tend to hinder or even altogether prevent the exploitation of some technological advances. For example, self-driving cars can be in wide-spread use only if they are legal, which in turn means that complex juridical issues, such as liabilities in the event of an accident, must be resolved.

Consumers ultimately desire bundles of goods and services that provide them with the highest overall quality of life for a given income. As such, they are mostly indifferent to the ways in which these bundles are provided. On the "supply side," employers' desire to substitute labor for capital is driven by a continuing rapid decline in the real quality-adjusted cost of computing and related technologies. So far, computerization (including robotics) has mostly influenced manual and cognitive routine tasks (Autor & Dorn, 2013). In years and decades to come, this influence will extend to non-routine tasks. In fact, we go as far as to suggest that in decades to come, the largest change will be felt in the highly appreciated and sought after office jobs that currently employ the bulk of the middle-class in developed countries.

4. Considering the Impact of Computerization One Occupation and One Task at a Time

The essence of Frey and Osborne's approach is to consider the task composition of each occupation and then evaluate task-by-task whether or not each task in each occupation will be computerized in the next two decades. In practice, a group of experts evaluated the tasks in about 10% of all occupations, after which the full list of occupations was estimated.

The value of the work of Frey and Osborne ultimately depends on three factors:

1. How well the tasks per occupation are defined (by BLS in the US).
2. How well the group of experts at Oxford University managed to relate the tasks of the seventy selected occupations, 10% of the total number of occupations, to existing and future technologies, including possible technological breakthroughs.
3. How representative the tasks of the 10% sample, which were evaluated in detail, are in relation to the tasks of the full list of occupations.

Upon applying the approach in other countries (without replicating the above three steps), a further question entails: how well US probabilities apply in the national context in question. If the reference year differs by more than a year or two, one might also wonder how well the probabilities apply over time, both because possibilities change and, more importantly, because occupations change as the most rewarding points for computerization are being exploited. It should also be emphasized that this approach does **not** consider possibly emerging new occupations or new/expanding tasks within existing occupations.

Even though there are a few issues of concern, based on our understanding, building on Frey and Osborne is indeed a valid way to gain some qualitative and quantitative understanding of how computerization may impact the future of jobs. We wish to emphasize, however, that the numbers we derive are rough approximations, not exact truths.

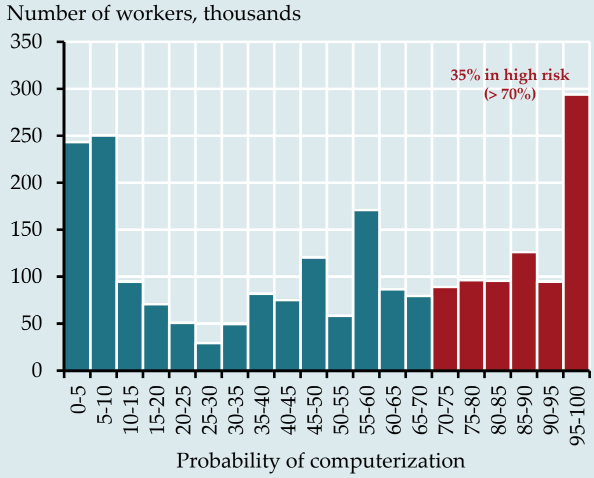
Frey and Osborne (2013) employ O*NET data and the *Standard Occupational Classification* by the *US Department of Labor*. They ended up considering 702 occupations in 2010. In what follows, we employ the same US data updated by two years in 2012, *Statistics Finland*'s data in 2011, and *Statistics Norway*'s data in 2013.

We convert the probabilities defined for US occupations to the *International Standard Classification of Occupations*.[4] Due to differences in the two classification systems, the number of occupations drops to 410 in the Finnish case and 374 in the Norwegian case. Our data nevertheless covers practically all workers with a valid occupation code in these countries.

Figure 1 in this report is analogous to *Figure III* of Frey and Osborne (2013, p. 37), although we neither employ the rolling average window of a width of 0.1 (our email exchange with Frey and Osborne on 13 Nov. 2013) nor provide a breakdown by main occupational categories. In Figure 1, the horizontal axis is the probability of computerization in five percentage point intervals. The vertical axis measures the headcount of workers in the occupations that fall within the probability of the computerization interval specified on the horizontal axis.

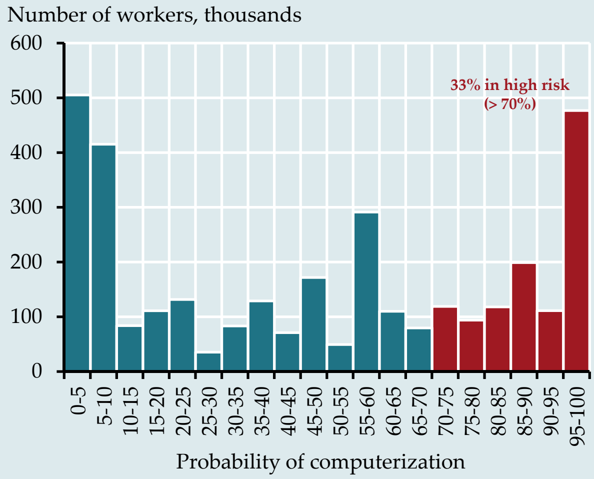
Figure 1 reveals that in all three countries – Finland (a), Norway (b), and the US (c) – there

1a Employment and computerization, **Finland**, 2011



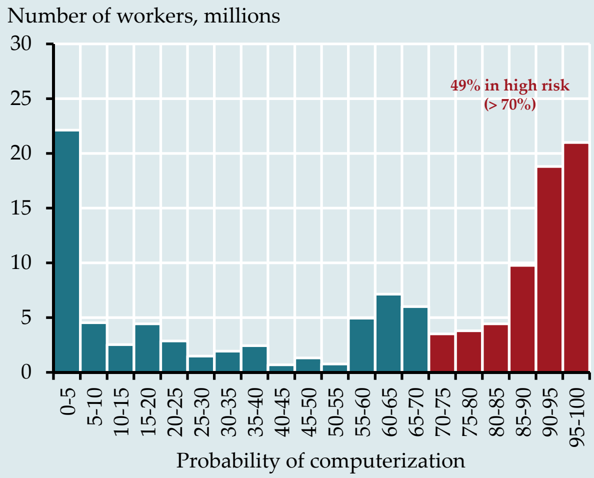
Data sources: *Statistics Finland* and Frey & Osborne (2013). ETLA

1b Employment and computerization, **Norway**, 2013



Data sources: *Statistics Norway* and Frey & Osborne (2013). ETLA

1c Employment and computerization, **The United States**, 2012



Data sources: Bureau of Labor Statistics and Frey & Osborne (2013). ETLA are distinct peaks at both ends of the distributions, which means that workers are typically either *quite sheltered* from or *quite threatened* by computerization rather than somewhere in between.

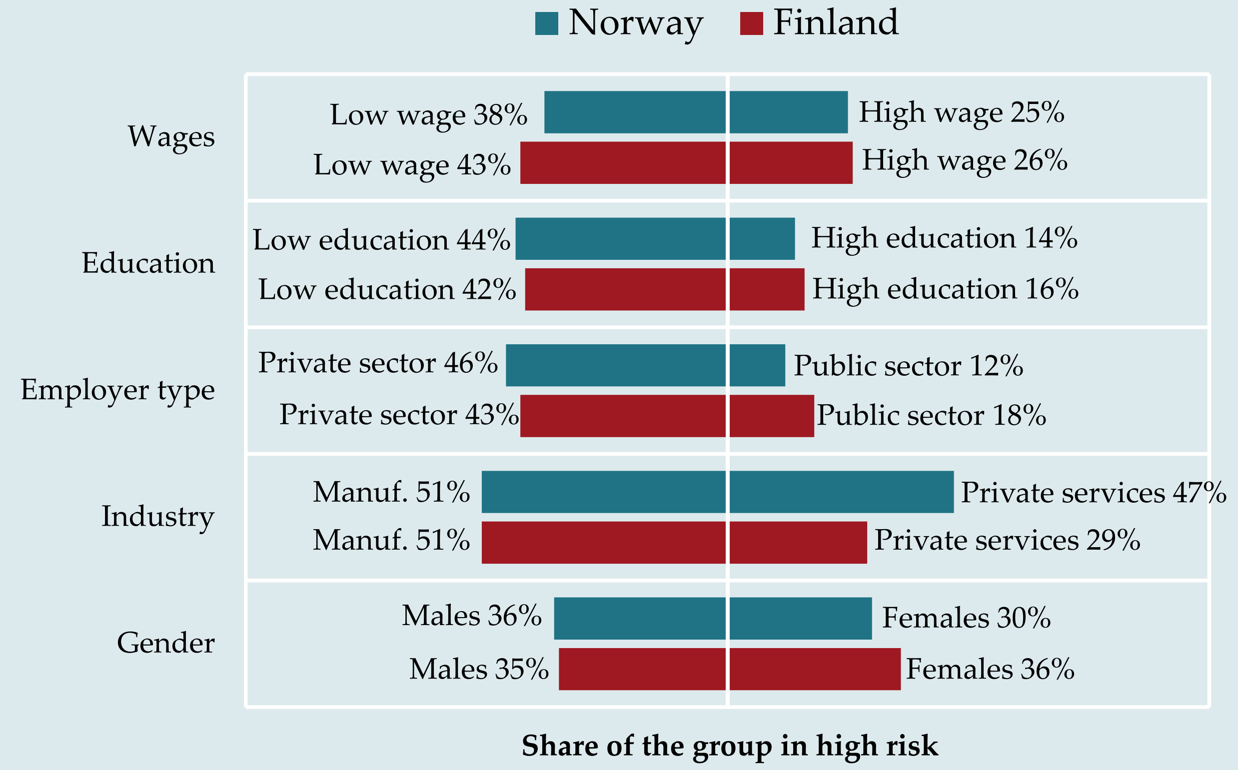
In Frey and Osborne (2013), occupations with a probability of computerization of *under 30%* are characterized as *low risk* and those with *over 70%* as *high risk*.

Our replication of Frey and Osborne, using data for 2012 rather than 2010, suggest that 49% of US employment is in the high-risk category. The corresponding share for Finland is 35% and for Norway 33%, i.e., 14–16%-points less than in the US. Compared to the US, Finland and Norway seem to have a greater mass in the middle of the distributions. While this is mostly due to the fact that occupational structures are more similar in Finland and Norway and are indeed different from those in the US, this is driven to a lesser extent by the fact that upon moving from the US to the international classification, we were forced to present averages for the occupational groups, which induces a slight "convergence towards the middle" phenomenon.[5] In order to gauge the magnitude of this effect, we re-calculated the US numbers by employing the ISCO classification. With the original classification, 49% of US employment was in the high-risk category in 2012; with the alternative classification, this share dropped to 45%. The share was still remarkably higher in the US case compared to those of Finland and Norway.

Figure 2 considers the susceptibility of computerization by different employer and worker characteristics in Finland and Norway.[6] The high-risk proportions regarding wages, education, employer type, and industry characteristics depict the same kind of picture in both countries: high-wage, high-education, service industry, and public sector jobs are more secure from computerization than low-wage, low-education, manufacturing, and private sector jobs.[7] With respect to gender, there is a slight difference between the countries: in Norway, women seem to be more sheltered from computerization than their male counterparts whereas, in Finland, the probabilities are almost equal.

Figure 2 suggests certain general tendencies, and as a consequence, it also conceals considerable variance. For instance, it is not the case that all highly educated workers would somehow

2 Proportions depicting the high risk of computerization by worker and employer characteristics



Data sources: Frey & Osborne (2013), *Statistics Finland*, and *Statistics Norway*. ETLA be "safe" in the face of computerization. While a high (and versatile) educational background does reduce the consequences of the ongoing turmoil induced by technological advancement, some occupations of highly educated workers – such as some accounting professions – may experience more substantial changes.

5. Computerization Offers Global Welfare Gains

Despite continuous fears to the contrary, at least since the dawn of the industrial revolution, concerns over mass unemployment caused by technological progress have not materialized. While huge amounts of labor effort have been saved, in due time, this effort has invariably found new uses.

It is nevertheless the case that in the ongoing transition, there is no guarantee that the relative balance between job creation and destruction will remain favorable. Even if it does, increasing labor market churning may perhaps lead to a higher "natural" rate of unemployment, whereby an increasing share of people is engaged in job searching or in acquiring new skills.

Our study ignores that both the content of tasks within occupations and the mix of occupations are in constant flux. It also ignores powerful societal forces that hinder change in occupational structure, which include at least the following: laws and regulations, conventions and standards, attitudes and values, difficulties in implementing complementary organizational changes, and powerful vested interests of "yesterday's winners" that influence politics.

Computerization affects all input and output markets worldwide. Technology will substitute for certain labor tasks, and workers will have to reallocate their labor supply. Productivity gains and intensifying competition will put downward pressure on market prices, thus supporting workers' buying power. New industries and occupations will emerge. Particularly in relation to innovation-intense countries, it will become increasingly important who develops, provides, implements, maintains, and refines the technologies we refer to within the computerization umbrella.

As far as labor market impacts are concerned, in our understanding, the current phase of computerization is arguably unique in its magnitude and speed of change. Furthermore, the phenomenon is truly worldwide and very general purpose in the sense that the range of technologies we refer to finds applications in all walks of life.

While we are optimistic about the ability of economies to adjust in the longer run, we foresee considerable difficulties in the shorter run simply because there seems to be too much job destruction and insufficient levels of job creation. This mismatch may manifest in stubborn and relatively high unemployment. A further concern in Finland and Norway is that the most lucrative business positions in the digital space – inventions of business models enabled by technological advances, the provision of popular digital platforms that establish multi-side markets (e.g., *AirBnB*, *Apple AppStore*, *Google Search*, *DropBox*, and *Uber*), and the control of associated brands – are largely held by foreign entities.

While computerization most likely increases global welfare, it is far from certain how these gains are distributed across countries. Whether or not technology races ahead of workers' ability to redeploy old and acquire new skills, computerization is one of the forces eliciting polarization in the labor market, a reality that should be fought with increasing emphasis on education and training.

6. The Ongoing Disruption Will Re-Define the Concept of Work

Based on our numerical calculations, we find that one-third of both Finnish and Norwegian employment will be highly susceptible to computerization in the next decade or two. While this share is large, it is over ten percentage points less than the corresponding share in the United States, which reflects cross-country differences in occupational structures. Low-wage and low-skill occupations appear to be more threatened. Service and public sector jobs are relatively more sheltered than those in manufacturing and the private sector.

The estimated impacts do not imply inevitable future mass unemployment. More than two centuries of industrial history suggests that saved labor tends to find new productive uses in due time. The method we employ does not take into account changes in the task content of occupations or the evolution in the mix of occupations. It also ignores powerful societal forces that hinder technological advancement. Despite these caveats, our findings suggest major future changes in employment.

Software and machines that operate autonomously, understand well the context in which they operate, and interact smoothly with their environment will revolutionize work in the next few decades. These advances can also increase the productivity of human tasks; thus, attainable standards of living may rise.

The future is not about humans *versus* machines. It is about humans and machines working together for more fulfilling professional and private lives (of humans worldwide).

Endnotes

[1] Offshoring, and globalization more generally, is another and related threat to current employment, but we do not address this issue here. As we employ the probabilities of computerization constructed by Frey and Osborne, this procedure obviously assumes that the task contents of occupations are similar in Finland, Norway, and the US. Naturally, we also directly replicate possible omissions embodied in the original analysis.

[2] The high-risk category is defined to include occupations with a probability of more than 70% of being replaced by computer-controlled equipment.

[3] Including data mining, digital sensing and actuation, machine vision, computational statistics, and other sub-fields of artificial intelligence.

[4] Conversion tables are available at http://v.gd/grjSKN.

[5] For instance, the probability of computerization for freight handlers (ISCO-08 group 9333) is an average of four occupational categories in the US classification, including managerial positions and blue-collar jobs. In the US case, the probabilities range from 7% for aircraft cargo handling supervisors to 85% for manual freight, stock, and material movers (upon deriving the probability used in the case of Finland and Norway, we simply used arithmetic means of the four US probabilities). On a related note, a few relatively large occupations are not assigned a probability in the original data, but they may be assigned one upon our averaging. For example, there is no probability for nursing assistants (SOC2010 31-1014), but there is for psychiatric aides (SOC2010 31-1013). These two occupational groups convert to healthcare assistants (ISCO-08 5321), whose probability of computerization is 47% (i.e., the US probability for psychiatric aides).

[6] We do not have complete comparative data on the US regarding the dimensions analyzed, so we concentrate here on Finland and Norway.

[7] High/low-wage occupations are categorized by the median wage level of all occupations in the economy; high-education groups include workers with a university degree (based on ISCED 1997 classes 6–8), and low-education groups consist of all other workers. Employer type (private/public) is based on business register information, and the manufacturing sector includes Nace Rev. 2 industry codes 10–43 and private services Nace Rev. 2 industry codes 45–82.

References

Autor, D. H., & Dorn, D. (2013). The growth of low-skill service jobs and the polarization of the US labor market. *American Economic Review, 103*(5), 1553–1597. http://dx.doi.org/10.1257/aer.103.5.1553

Autor, D. H., Dorn, D., & Hanson, G. H. (2013). The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review, 103*(6), 2121–2168. http://dx.doi.org/10.1257/aer.103.6.2121

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. [Article]. *Quarterly Journal of Economics, 118*(4), 1279–1333. http://dx.doi.org/10.1162/003355303322552801

Brynjolfsson, E., & Hitt, L. M. (2000). Beyond computation: Information technology, organizational transformation and business performance. *Journal of Economic Perspectives, 14*(4), 23–48.

Evans, D. (2012). The internet of everything: How more relevant and valuable connections will change the world. *Cisco Internet Business Solutions Group*. http://www.cisco.com/web/about/ac79/docs/innov/IoE.pdf

Frey, C. B., & Osborne, M. A. (2013). The future of employment: How susceptible are jobs to computerisation? *OMS Working Papers, September 18*. http://www.futuretech.ox.ac.uk/sites/futuretech.ox.ac.uk/files/The_Future_of_Employment_OMS_Working_Paper_0.pdf

Kushida, K. E., Murray, J., & Zysman, J. (2015). Cloud computing: From scarcity to abundance. *Journal of Industry, Competition and Trade, 15*(1), 5–19. http://dx.doi.org/10.1007/s10842-014-0188-y

Pajarinen, M., & Rouvinen, P. (2014). Computerization threatens one third of Finnish employment. *ETLA Briefs, 22*. http://pub.etla.fi/ETLA-Muistio-Brief-22.pdf