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Are New Technologies Changing the Nature of Work? The Evidence So Far

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THE FUTURE OF SKILLS AND ADULT LEARNING

ABOUT THIS STUDY

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SUMMARY

In recent years, ground breaking advances in artificial intelligence and their implications for automation technology have fuelled speculation that the very nature of work is being altered in unprecedented ways. News headlines regularly refer to the "changing nature of work," but what does it mean? Is there evidence that work has already been transformed by the new technologies? And if so, are these changes more dramatic than those experienced before?

In this paper, Kristyn Frank and Marc Frenette offer insights on these questions, based on the new research they conducted with their colleague Zhe Yang at Statistics Canada. Two aspects of work are under the microscope: the mix of work activities (or tasks) that constitute a job, and the mix of jobs in the economy. If new automation technologies are indeed changing the nature of work, the authors argue, then nonautomatable tasks should be increasingly important, and employment should be shifting toward occupations primarily involving such tasks.

According to the authors, nonroutine cognitive tasks (analytical or interpersonal) did become more important between 2011 and 2018. However, the changes were relatively modest, ranging from a 1.5 percent increase in the average importance of establishing and maintaining interpersonal relationships, to a 3.7 percent increase in analyzing data or information. Routine cognitive tasks – such as data entry – also gained importance, but these gains were even smaller. The picture is less clear for routine manual tasks, as the importance of tasks for which the pace is determined by the speed of equipment declined by close to 3 percent, whereas other tasks in that category became slightly more important.

Looking at longer-term shifts in overall employment, between 1987 and 2018, the authors find a gradual increase in the share of workers employed in occupations associated with nonroutine tasks, and a decline in routine-task-related occupations. The most pronounced shift in employment was away from production, craft, repair and operative occupations toward managerial, professional and technical occupations. However, they note that this shift to nonroutine occupations was not more pronounced between 2011 and 2018 than it was in the preceding decades. For instance, the share of employment in managerial, professional and technical occupations increased by 1.8 percentage points between 2011 and 2018, compared with a 6 percentage point increase between 1987 and 2010.

Most sociodemographic groups experienced the shift toward nonroutine jobs, although there were some exceptions. For instance, the employment share of workers in managerial, professional and technical occupations increased for all workers, but much more so for women than for men. Interestingly, there was a decline in the employment shares of workers in these occupations among those with a post-secondary education. The explanation for this lies in the major increase over the past three decades in the proportion of workers with post-secondary education, which led some of them to move into jobs for which they are overqualified.

The authors explain that these employment shifts may be caused by factors – other than technology-induced demand for skills – that change the industrial structure of the economy. For example, higher demand for health services due to population aging may increase the share of employment in health-related occupations. Their analyses show that these other factors explain most of the increase in employment share in service occupations, about two-thirds of the decrease in production, craft, repair and operative occupations, and roughly 40 percent of the increase in managerial, professional and technical occupations. Their estimates of changes in the average importance of various tasks, nevertheless, remain significant.

It is important that policy-makers be informed of the evolution of the nature of work as new technologies are further integrated into the workplace, given the potential implications for policy development. This study has shown that, although recent advances in automation technologies have affected what workers do on the job and which occupations they work in, overall, the changes are not substantive. In other words, it may be premature to conclude that new technologies have altered the nature of work.

RÉSUMÉ

Ces dernières années, les progrès rapides de l'intelligence artificielle et leur incidence sur les technologies d'automatisation ont alimenté l'hypothèse d'une transformation sans précédent de la nature même du travail. Les grands titres évoquent souvent les mutations du travail, mais qu'en est-il exactement ? Dispose-t-on de preuves confirmant que les nouvelles technologies ont déjà transformé les emplois ? Si c'est le cas, ces transformations sont-elles plus profondes que les précédentes ?

Dans cette étude, Kristyn Frank et Marc Frenette examinent ces questions en s'appuyant sur les nouvelles recherches qu'ils ont menées à Statistique Canada avec leur collègue Zhe Yang. Ils scrutent deux aspects du travail : la combinaison d'activités (ou tâches) qui constituent un emploi et la combinaison des emplois dans l'économie. Si les technologies d'automatisation modifient effectivement la nature du travail, soutiennent-ils, on devrait observer une importance accrue des tâches non automatisables et une réorientation du marché de l'emploi vers des professions principalement axées sur ce type de tâches.

Et de fait, les tâches cognitives non routinières (analytiques ou interpersonnelles) ont gagné en importance de 2011 à 2018. Mais on parle ici d'une progression moyenne relativement faible, comprise entre 1,5 p. 100 pour ce qui est d'établir et d'entretenir des relations interpersonnelles et 3,7 p. 100 pour l'analyse de données ou d'informations. L'importance des tâches cognitives routinières (comme l'entrée de données) a aussi augmenté, mais encore plus faiblement. Le tableau est moins clair pour les tâches manuelles routinières, l'importance des tâches dont le rythme est déterminé par la vitesse des équipements ayant reculé de près de 3 p. 100, alors que celle d'autres tâches de cette catégorie a légèrement augmenté.

À l'examen des tendances à long terme, soit de 1987 à 2018, les auteurs notent une augmentation graduelle de la proportion de travailleurs exerçant des professions axées sur des tâches non routinières et, simultanément, une diminution des emplois basés sur des tâches routinières. La tendance la plus marquée concerne le transfert d'emplois en production, artisanat, réparation et opérations vers des métiers administratifs, professionnels et techniques. Mais ce transfert vers des métiers non routiniers ne s'est pas accentué davantage entre 2011 et 2018 qu'entre 1987 et 2010. Par exemple, la proportion d'emplois administratifs, professionnels et techniques n'a augmenté que de 1,8 points de pourcentage de 2011 à 2018 par rapport à 6 points de pourcentage de 1987 à 2010.

Cette transition vers des emplois non routiniers s'étend à la plupart des groupes sociodémographiques, à quelques exceptions près. Ainsi, la part des travailleurs occupant des emplois administratifs, professionnels et techniques a partout augmenté, mais beaucoup plus chez les femmes que chez les hommes. Sans doute plus étonnant, on note une diminution de la proportion des travailleurs ayant fait des études postsecondaires qui arrivent à décrocher des postes pour ces mêmes emplois. Ce qui s'explique par la forte hausse de la proportion de ces travailleurs observée depuis 30 ans, et la nécessité pour certains d'entre eux d'accepter des emplois pour lesquels ils sont surqualifiés.

Au-delà de la demande pour des compétences technologiques, ces transferts d'emplois pourraient s'expliquer par d'autres facteurs qui modifient la structure industrielle de l'économie. Le vieillissement de la population et la demande pour les soins de santé qui s'ensuit, par exemple, peuvent faire augmenter la part des emplois dans le domaine de la santé. Selon les analyses des auteurs, ces autres facteurs expliquent l'essentiel de la hausse des parts d'emplois dans le secteur des services, les deux tiers de leur recul dans les secteurs de la production, de l'artisanat, de la réparation et des opérations, et environ 40 p. 100 de l'augmentation des emplois administratifs, professionnels et techniques. Même en tenant compte de ces autres facteurs, leur estimation des variations de l'importance moyenne de diverses tâches reste significative.

Il est important que les décideurs suivent l'évolution de la nature du travail au fur et à mesure de l'intégration des nouvelles technologies dans les lieux de travail compte tenu des impacts possibles sur les politiques publiques. Cette étude montre que les récents progrès des technologies de l'automatisation ont certes modifié les tâches des travailleurs et les emplois qu'ils occupent, mais qu'on ne peut encore parler d'une transformation fondamentale. Autrement dit, il est sans doute prématuré d'affirmer que les nouvelles technologies ont d'ores et déjà transformé la nature du travail.

TECHNOLOGY AND JOBS: AN INTRICATE RELATIONSHIP

Over the last few years, concerns about the impact of technology on jobs and the future of work have been a focus of public debates in Canada and worldwide. This question has also drawn the attention of policy-makers, who often have an active interest in monitoring such changes. Many policies, particularly those that support workforce development, can be productively informed by a clear understanding of what is happening in labour markets.

The way people work is forever changing, so what explains current concerns? Reports of major breakthroughs in artificial intelligence (AI) may be fuelling the perception that jobs — and work in general — are about to be transformed in an unprecedented way. Granted, the capabilities of AI-based technologies are truly revolutionary. Translation and speech recognition are good examples. But have these innovations already changed the nature of work per se? And if so, are these changes more dramatic than anything experienced before? A new Statistics Canada study is the first to investigate these questions, using the most recent Canadian data (Frank, Yang and Frenette 2021). This paper is a companion piece that takes a deeper look at the concepts used and the evidence presented in that study.

It is important to define the "nature of work," especially when seen through the lens of technological change. What people do at work entails a mix of tasks (that is, work activities) of different types and of varying degrees of importance. Technology alters this mix at the job level and at the workforce level. By automating some tasks, it allows workers to spend more time on other work activities or even take up new responsibilities. The introduction of ATMs and its effects on the role of bank tellers is a perfect example of how technology alters the mix of activities at the job level. Freed from dispensing and depositing money, bank tellers switched to providing other banking services, tasks which were previously performed exclusively by specialized bank employees (Bessen 2015).

Technology also alters the mix of jobs, thus changing the nature of work at the level of the workforce. On one hand, jobs transformed by technology may employ more people. For instance, by making workers more productive, technology makes the goods and services they produce more affordable. As demand for these goods and services goes up, more workers are hired. Going back to the example of bank tellers, Bessen (2015) shows that technology did reduce their number per bank branch, but more branches were opened and the total number of bank tellers in the labour force went up. On the other hand, technology may encourage workers to change occupations. As the demand for workers performing automatable tasks diminishes, and that for workers adept at hard-to-automate tasks goes up, workers are likely to respond by shifting away from occupations susceptible to automation toward those that are not. Taken together, changes in the relative importance of various tasks within an occupation and changes in the distribution of workers across occupations transform the nature of work toward hard-to-automate work activities and jobs.

Automation technologies introduced in the second half of the twentieth century, such as robots and computers, replicated and took over work activities that could be broken down and codified by humans before being delegated to a machine. Whether manual (like drilling a hole of a predefined diameter) or cognitive (like alphabetizing a list of names), these tasks were routine, consisting of well-defined steps that are organized in a fixed sequence.

Research from Europe and the United States has shown that, between 1970 and the early 2000s, employment shifted from predominantly routine work activities (either cognitive or manual) to nonroutine activities that were difficult to computerize at the time (Autor, Levy and Murnane 2003; Hardy, Keister and Lewandowski 2015; Levy and Murnane 2013; Spitz-Oener 2006). In Europe, increased educational attainment played a central role in facilitating this shift, as nonroutine tasks required highly educated workers and increased the demand for those with post-secondary degrees. In the US, up to 60 percent of the increase in the demand for college-educated workers from 1970 to 1998 was due to the growing importance of nonroutine cognitive tasks that require creativity or solving complex problems (Autor, Levy and Murnane 2003).

Recent advances in AI may facilitate automation of more complex cognitive tasks than has been the case until now. Compared with automation technologies developed in the past, AI-based innovations are more flexible. They learn how to perform tasks and adjust to the changing environment by detecting patterns in available data, and require minimal training by humans. Siri, Apple's commercial speech-recognition system introduced in 2011, is a perfect example of a machine automating tasks that cannot be called routine in a traditional sense. It highlights an important difference between automatable and routine. These new technologies could potentially affect higher-skilled, knowledge-based jobs, if they prove effective and are widely adopted (Brandes and Wattenhofer 2016; OECD 2016; Susskind and Susskind 2015). At the level of the entire workforce, the adoption of AI-based technologies could extend, if not accelerate, the ongoing shifts in the demand for skills and, as a result, employment toward complex cognitive tasks that AI cannot yet perform, such as motivating teammates or resolving conflicts. In the same vein, some nonroutine manual tasks, like equipment installation or repair, are currently out of reach for AI and are also likely to continue employing human workers.

From a policy perspective, any kind of work transformation can have important implications if its impact is more pronounced for population groups that are known to be more susceptible to job loss and long-term unemployment, or if it affects new groups of workers that previously were not the object of policy concern. For example, if jobs increasingly require proficiency in soft skills, such as high-level communication and people management, then younger workers may be at a disadvantage. These skills are normally developed over the course of a career and are more common among older individuals. Similarly, if complex technical jobs, like data analytics, are being taken over by machines that are superior to humans in identifying patterns in data, then one might wonder if having a university degree, currently a prerequisite for data scientists, will continue to provide protection against job loss.

The new Statistics Canada study investigates how these trends are playing out in Canada by looking at the following three questions:

1. Amid advances in automation technology in the last decade, did routine tasks become significantly less important than nonroutine tasks between 2011 and 2018?
2. Looking at the last thirty years (1987-2018) for context and perspective on these short-term trends, to what extent have workers shifted away from occupations predominantly involving routine tasks to those involving nonroutine tasks? Were these shifts more pronounced in the last decade than before?
3. Do these employment trends vary by sex, age and level of education?

It is also important to examine the extent to which these employment shifts result from factors unrelated to technology-induced changes in demand for skills. For instance, the aging of the Canadian population is expected to result in higher demand for health care services (Maestas, Mullen and Powell 2016). With rising employment in health occupations, which are primarily nonroutine manual and cognitive, the relative importance of nonroutine activities in the workforce will inevitably grow. Making this distinction is also part of the analysis.

WHERE TO LOOK FOR EVIDENCE ON THE CHANGING NATURE OF WORK IN CANADA

Statistics Canada's Labour Force Survey (LFS), which contains information about the employment status of Canadians, provides the most recent relevant data for this study. This survey is used, for example, to calculate employment and unemployment rates, and provides other information on the current state of the labour market.[1] This study is based on a sample from the survey that excludes self-employed individuals as they tend to be less susceptible to automation than paid employees (Frenette and Frank 2020).[2]

Since the study is concerned with work tasks, it requires measuring what people do on the job. How does one do that? In his 2015 paper on the history and future of workplace automation, David Autor describes the various challenges that empirical researchers face when studying how technology and labour markets interact, and the methods used to measure tasks. Education and work experience are often used as proxies for skills. The drawback to this approach is that what people *can* do does not always correspond to what they *actually do* at work. In another approach, occupations serve as proxies for work tasks. This information is available in the Labour Force Survey. But occupations, as identified by a unique code assigned to them by the National

[1] Not all groups of Canadians are represented in the survey. For example, the LFS data exclude individuals living on reserves and other Aboriginal settlements in the provinces, full-time members of the Canadian Armed Forces, the institutionalized population and households in remote areas with low population density (Statistics Canada 2017). Together, these groups represent approximately 2 percent of the Canadian population aged 15 and over.

[2] One possible explanation is that the main objective of self-employed individuals is to create employment for themselves, rather than focus on growth, as do large companies with many employees (Sorgner 2017).

Occupational Classification (NOC), can be too numerous and cumbersome to use. And aggregating them into major occupational groups, as Autor explains, masks differences in task content across the occupational groups.

Objective data on the task content of individual occupations help overcome these issues. Such data can come from three sources: employers, employees and experts. Some researchers use ads posted by employers describing job responsibilities to study changes in the occupational task content. For example, Atalay et al. (2017) traced job evolution from 1960 to 2000 based on 4 million job ads posted in major newspapers during that period. Dillender and Forsythe (2019) investigated the transformation of office support jobs, using ads posted online between 2007 and 2016. While novel and creative, this approach is not without shortcomings. Actual activities on the job might differ from those listed in the ads and may vary with workers' qualifications. Moreover, it is impossible to determine the relative importance of the listed tasks and to know whether some tasks are missing from the list.

Asking employees directly what they do at work is another option. Examples include the Skills and Employment Survey in the United Kingdom and the Employment Surveys of the Federal Institute for Vocational Education and Training in Germany.[3,4] While such surveys provide unique insights into the complexities and diversity of work activities, they only exist in a handful of countries, are costly to implement and require meticulous gathering of consistent data that can be aggregated and compared.

The third option is to rely on experts. Many empirical researchers use the Occupational Information Network (O*NET) developed by the US Department of Labor, which assigns standardized job descriptors externally validated by statistical agencies to thousands of occupations. As Autor notes, this approach has its own caveats. For example, being standardized, job descriptors cannot take into account how the task contents of the same occupation vary from firm to firm, depending on employees' skills, firm structure and other factors. Nevertheless, the O*NET is widely used in empirical research because of its consistency and availability. Moreover, it is unique in ranking the relative importance of activities in each occupation, which is essential for the purpose of this research.

This study merges the LFS data on occupations held by employed workers in Canada with the occupational descriptors in the O*NET. The following five distinct categories include a total of 16 relevant tasks: [5,6]

1. Nonroutine cognitive analytical tasks: analyzing data or information; thinking creatively; and interpreting the meaning of information for others.

[3] "Skills and Employment Survey," Cardiff University, https://www.cardiff.ac.uk/research/explore/find-a-project/view/626669-skills-and-employment-survey-2017.
[4] Federal Institute for Vocational Education and Training, https://www.bibb.de/en/index.php.
[5] Although the O*NET provides data for many work activities, this study selected 16 work activities considered to be representative of five distinct task groups, as established by previous studies (e.g., Autor and Handel 2013; Hardy, Keister and Lewandowski 2015).
[6] While previous research created composite measures for each of these task groups, each task was examined separately in the current study (see Górka et al. 2017 and Hardy, Keister and Lewandowski 2015). This way, the risk of misclassifying tasks as routine or nonroutine could be avoided, and it was possible to provide a more detailed account of how the importance of various tasks has changed over time (Green 2012).

2. Nonroutine cognitive interpersonal tasks: establishing and maintaining interpersonal relationships; guiding, directing and motivating subordinates; and coaching and developing others.
3. Routine cognitive tasks: repeating the same tasks; being exact or accurate; and the degree to which work activities are structured.[7]
4. Routine manual tasks: working at a pace determined by speed of equipment; controlling machines and processes; and making repetitive motions.
5. Nonroutine manual tasks:[8] operating vehicles, mechanized devices or equipment; using hands to handle, control or feed objects, tools or controls; using spatial orientation;[9] and using manual dexterity.

The average of each task's respective ratings in the O*NET, weighted by the number of workers employed in an occupation using this task, provides a measure of the importance of each task for the workforce as a whole.[10] These measures are then compared between 2011 and 2018.[11]

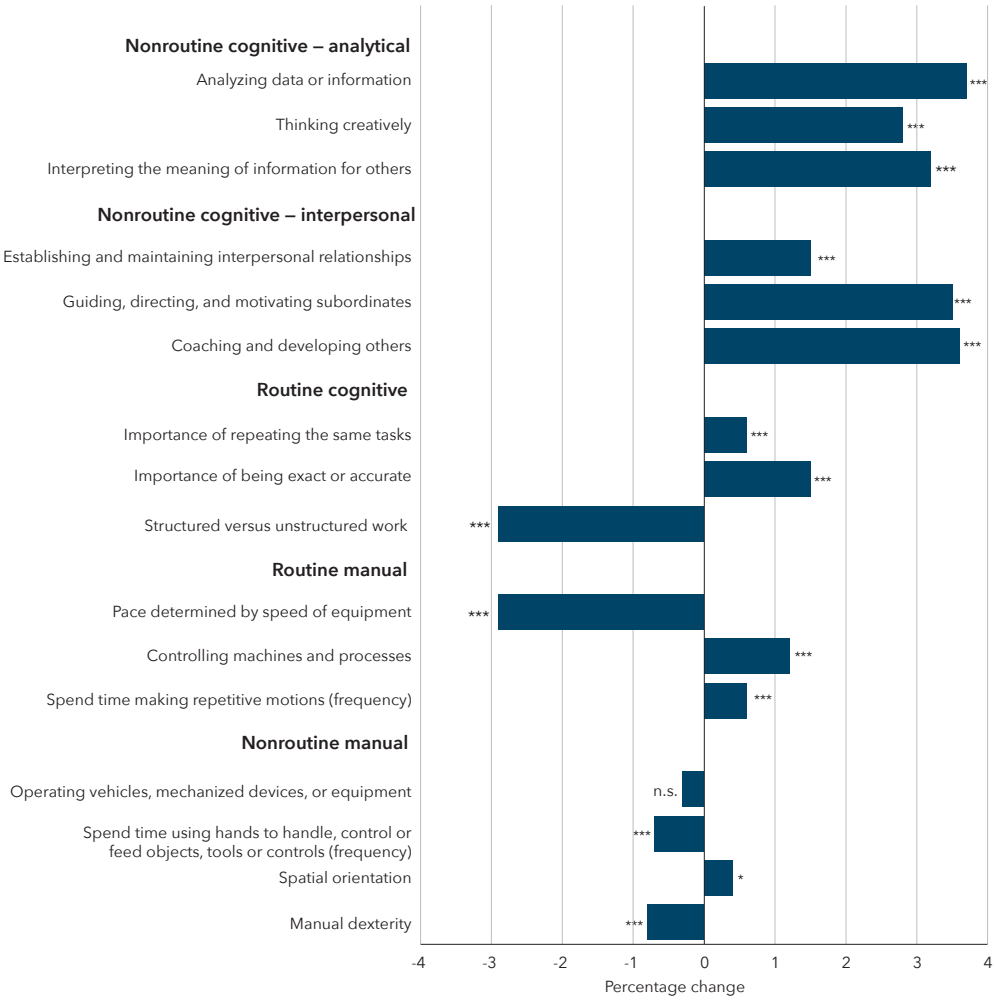
Before reporting the results of this exercise, some caveats are in order. One decade may seem like a relatively short period to measure changes in occupational tasks. Also, the new technologies that emerged during this recent period may still be largely at the development stage, while at the same time more mature technologies were still being adopted in Canadian workplaces. For example, the density of industrial robots in Canada increased by almost 50 percent between 2010 and 2015, which may have affected the tasks of workers employed in manufacturing.[12] Still, gathering insights into the changing nature of work is not premature. It will provide a useful benchmark from which to gauge the evolving importance of tasks as AI-based technologies gain traction.

WHAT HAPPENED TO WORK TASKS IN THE LAST DECADE?

The first finding is that, on average, nonroutine cognitive tasks, whether analytical or interpersonal, gained in importance between 2011 and 2018, but the gains were moderate (figure 1).[13] The largest increases were observed for analyzing data or

[7] In defining work as structured or unstructured, the O*NET refers to the extent to which jobs allow the workers to determine their tasks, priorities and goals, reflecting the degree of autonomy workers have in their jobs.
[8] In the relevant literature, this category of tasks is referred to as "nonroutine manual/physical tasks."
[9] The O*NET defines spatial orientation as the ability to know an individual's location in relation to the environment or to know where other objects are in relation to the individual.
[10] For most tasks, importance scores range from 1 (not important) to 5 (extremely important). However, three tasks – structured versus unstructured work, spend time making repetitive motions, and spend time using hands to handle, control or feed objects, tools or controls – are based on different scales. The degree of structure at work is measured on a scale ranging from 1 (no freedom) to 5 (a lot of freedom). The remaining two tasks are based on a frequency scale ranging from 1 (never) to 5 (continually/almost continually). For more details, refer to Frank, Yang and Frenette (2021) and the National Center for O*NET Development (n.d.).
[11] The period between 2011 and 2018 was chosen because the data on occupational codes necessary for linking the LFS with the O*NET were available only starting in 2011. See Frank, Yang and Frenette (2021) for more details.
[12] Based on authors' calculations of data which define robot density as the number of multipurpose industrial robots per 10,000 persons employed in manufacturing (International Federation of Robotics 2016).
[13] Importance scores are measured on a scale of 1 to 5. All changes discussed in this section are statistically significant at the 5 percent level unless otherwise noted. For the mean importance scores for each work activity in 2011 and 2018, see Table A1.

Figure 1. Change in the average importance of occupational tasks, Canada, 2011-2018 (percent)



Sources: Authors' calculations based on Statistics Canada, Labour Force Survey (2011 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701; US Department of Labor, O*NET (2011 and 2018), https://www.onetonline.org.
Notes: The importance scale comes from the O*NET system. For all but three occupational tasks, the importance scores range from 1 (not important) to 5 (extremely important). The exceptions are "structured versus unstructured work," which is measured on a scale ranging from 1 (no freedom) to 5 (a lot of freedom); and "spend time making repetitive motions" and "spend time using hands to handle, control or feed objects, tools or controls," which are based on a frequency scale ranging from 1 (never) to 5 (continually or almost continually). The percentage change was calculated using multiple regressions.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, n.s. = not statistically significant

information (3.7 percent), coaching and developing others (3.6 percent), guiding, directing and motivating others (3.5 percent), interpreting the meaning of information for others (3.2 percent), and thinking creatively (2.8 percent). The importance of establishing and maintaining interpersonal relationships also increased but by a smaller magnitude (1.5 percent).[14]

Second, routine cognitive tasks in Canadian jobs have also become more important but not by as much as the nonroutine ones. For example, the importance of being exact or accurate and of repeating the same tasks went up on average by 1.5 and 0.6 percent, respectively. These are tasks like data entry and checking entries in a ledger. The degree of workers' autonomy in determining their tasks also increased by 1.6 percent.

Third, the change in the average importance of routine manual tasks between 2011 and 2018 varied depending on the task. For example, the pace at which workers' tasks were determined by the speed of equipment decreased by 2.9 percent, while the importance of controlling machines and processes (excluding computers or vehicles) increased by 1.2 percent. Making repetitive motions became slightly more important (by 0.6 percent).

Finally, across the nonroutine manual (physical) tasks, average importance fell slightly. The largest decrease was found for manual dexterity (0.8 percent), followed by a decline in the time workers spent using their hands to handle, control or feed objects, tools or controls (0.7 percent). However, spatial orientation became slightly more important (0.4 percent). Changes in the importance of operating vehicles, mechanized devices or equipment were not statistically significant.

To summarize, in the last decade, both routine and nonroutine cognitive tasks became, on average, more important – albeit moderately so – with the largest changes recorded for nonroutine tasks. The picture is less clear when it comes to manual tasks, which increased in importance in some cases and decreased in others. These findings could be due to changes in task importance at the level of occupations in the O*NET descriptors, which are reviewed on a regular basis. However, separate analyses (not shown) revealed very small, if any, changes in the descriptors between 2011 and 2018. Alternatively, the findings may be due to shifts in the shares of workers employed across occupations. These are examined in the next section for the period from 1987 to 2018 to provide context and a longer-term perspective on the changes observed in the past ten years.

IS EMPLOYMENT SHIFTING ACROSS OCCUPATIONAL-TASK GROUPS?

To answer this question, all occupations were grouped along two dimensions: the extent to which they involve tasks that are routine or nonroutine; and the extent to

[14] Although comparing these figures with those for previous years or other countries would be informative, no comparable results are available.

which they involve tasks that are cognitive or manual. This approach, which builds upon and extends previous research,[15] yields the following four occupational-task groups:[16,17]

1. Managerial, professional and technical occupations – specialized in nonroutine cognitive tasks.
2. Service occupations – specialized in nonroutine manual tasks.
3. Sales, clerical and administrative support occupations – specialized in routine cognitive tasks.
4. Production, craft, repair and operative occupations – specialized in routine manual tasks.

Looking at employment shares across these four occupational-task groups, it is evident that they changed considerably over the 31-year period.[18] The proportion of Canadian workers employed in occupations involving primarily nonroutine tasks increased, while that in occupations involving primarily routine tasks decreased (see figures 2 and 3). Notably, however, these employment shifts occurred gradually over the three decades and did not amplify in the last decade, even though it was a period marked by rapid advances in AI and machine learning.[19]

The most pronounced shift in employment was from production, craft, repair and operative occupations (routine manual tasks) to managerial, professional and technical occupations (nonroutine cognitive tasks). In 1987, production, craft, repair and operative occupations had the highest share of Canadian workers (29.7 percent, figure 2). By 2018, this share had fallen by 7.5 percentage points (a 25.3 percent decrease, figure 3). During the same period, the share of managerial, professional and technical occupations grew by 7.5 percentage points. By 1994, it had surpassed the share held by production, craft, repair and operative occupations. By 2018, 31.2 percent of workers were employed in managerial, professional and technical occupations, compared with 22.2 percent of workers employed in production, craft, repair and operative occupations.

[15] Autor, Levy and Murnane (2003) developed the framework, which was subsequently used by Oschinski and Wyonch (2016). This study extends the work of the latter in three important ways. First, it extends the period for the analysis to 2018. Second, instead of combining routine occupations, the manual and cognitive occupational-task groups were considered separately. And third, trends are reported along three socio-demographic characteristics: gender, age and level of education. This occupations-based approach, albeit less specific than the tasks-based approach in the preceding section, provides a longer-term perspective on how jobs changed over time, and helps put more recent trends in context.

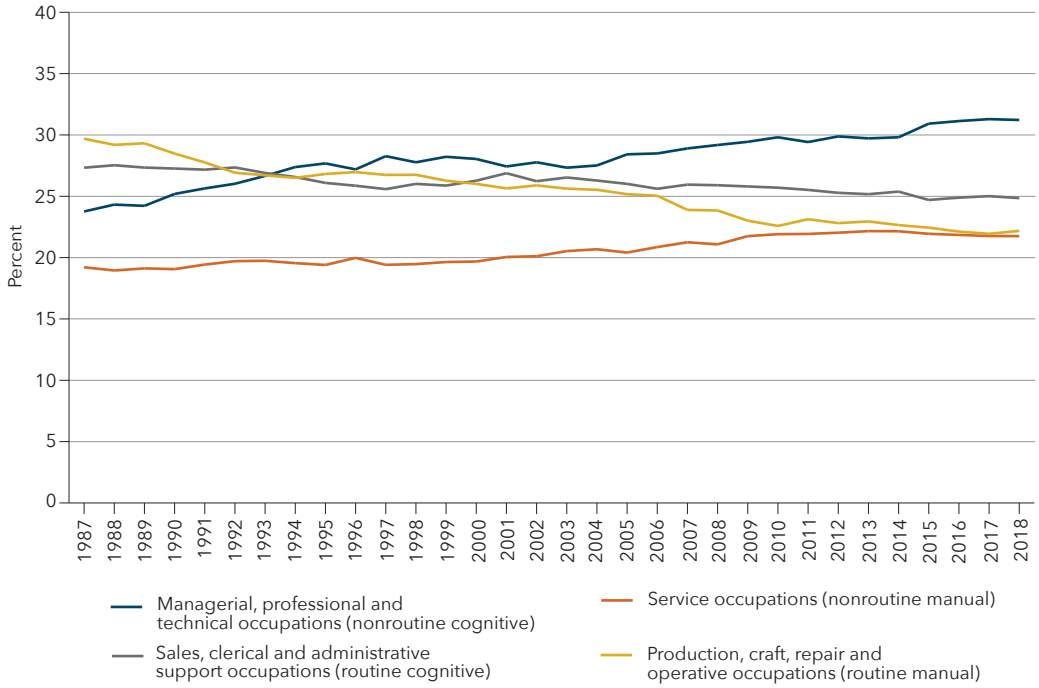
[16] Note that in this classification occupations are grouped based on the tasks performed on the job, not the industry where these jobs are. For example, some occupations that may be prevalent in service-providing sectors, such as education services or health services, belong to the category of managerial, professional and technical occupations rather than service occupations. This is because they involve nonroutine cognitive rather than manual tasks. Hence, occupational-task groups are not the same as industries or economic sectors.

[17] For details on this multistage process, refer to Frank, Yang and Frenette (2021).

[18] These changes were statistically significant at the 0.1 percent level.

[19] Additional analyses by firm size found similar patterns. Note, however, that the study examines only changes between 1998 and 2018, as data on firm size were not available in the LFS prior to 1998. However, the magnitudes of the increase for service occupations and of the decrease for production, craft, repair and operational occupations were substantially bigger for larger firms (more than 500 employees) than for smaller firms (less than 20 employees). This finding may be attributed to the greater financial resources of larger firms, which may allow them to invest more in new technologies than smaller firms.

Figure 2. Employment shares by occupational-task group, Canada, 1987-2018 (percent)



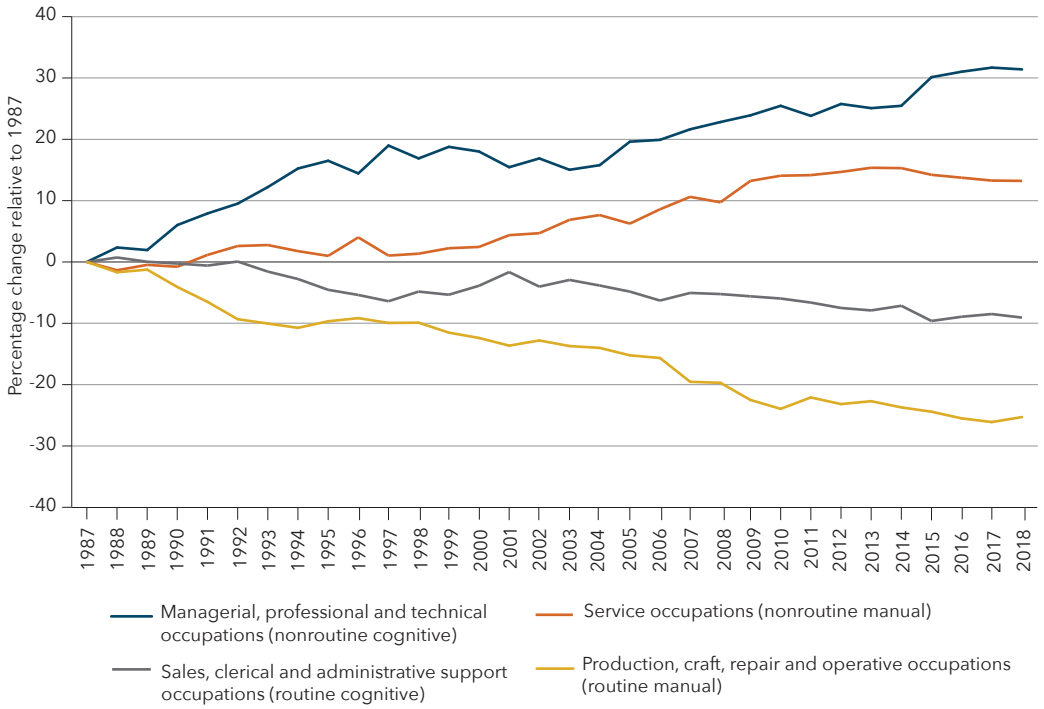
Source: Statistics Canada, Labour Force Survey (1987-2018), https://www.statcan.gc.ca/eng/survey/household/3701.

Service occupations (nonroutine manual tasks) also employed increasingly more workers over this period, though to a lesser extent than managerial, professional and technical occupations. Since 1987, the employment share in service occupations increased by 2.5 percentage points, reaching 21.8 percent by 2018 (figure 2). Service occupations accounted for the lowest share of the workforce throughout the entire 31-year period. In recent years, however, employment shares in service occupations appear to be converging with those in production, craft, repair and operative occupations. Of note, both groups involve primarily manual tasks, nonroutine and routine, respectively.

Since 2010, the employment share in service occupations has remained relatively stable (figure 2). As figure 1 shows, on average, the importance of nonroutine manual tasks declined somewhat between 2011 and 2018. Together, these results may suggest that complex manual tasks are becoming increasingly automatable, which would reduce the importance or frequency of such tasks for service workers. Whether service workers are adjusting by focusing on more productive tasks that are still out of reach for technology remains to be seen. For the moment, employment shares remain steady in this broad occupational group.

The proportion of workers employed in sales, clerical and administrative support occupations (routine cognitive tasks) also decreased by 2.5 percentage points

Figure 3. Change in employment shares by occupational-task group, Canada, 1987-2018 (percent)



Source: Statistics Canada, Labour Force Survey (1987-2018), https://www.statcan.gc.ca/eng/survey/household/3701.

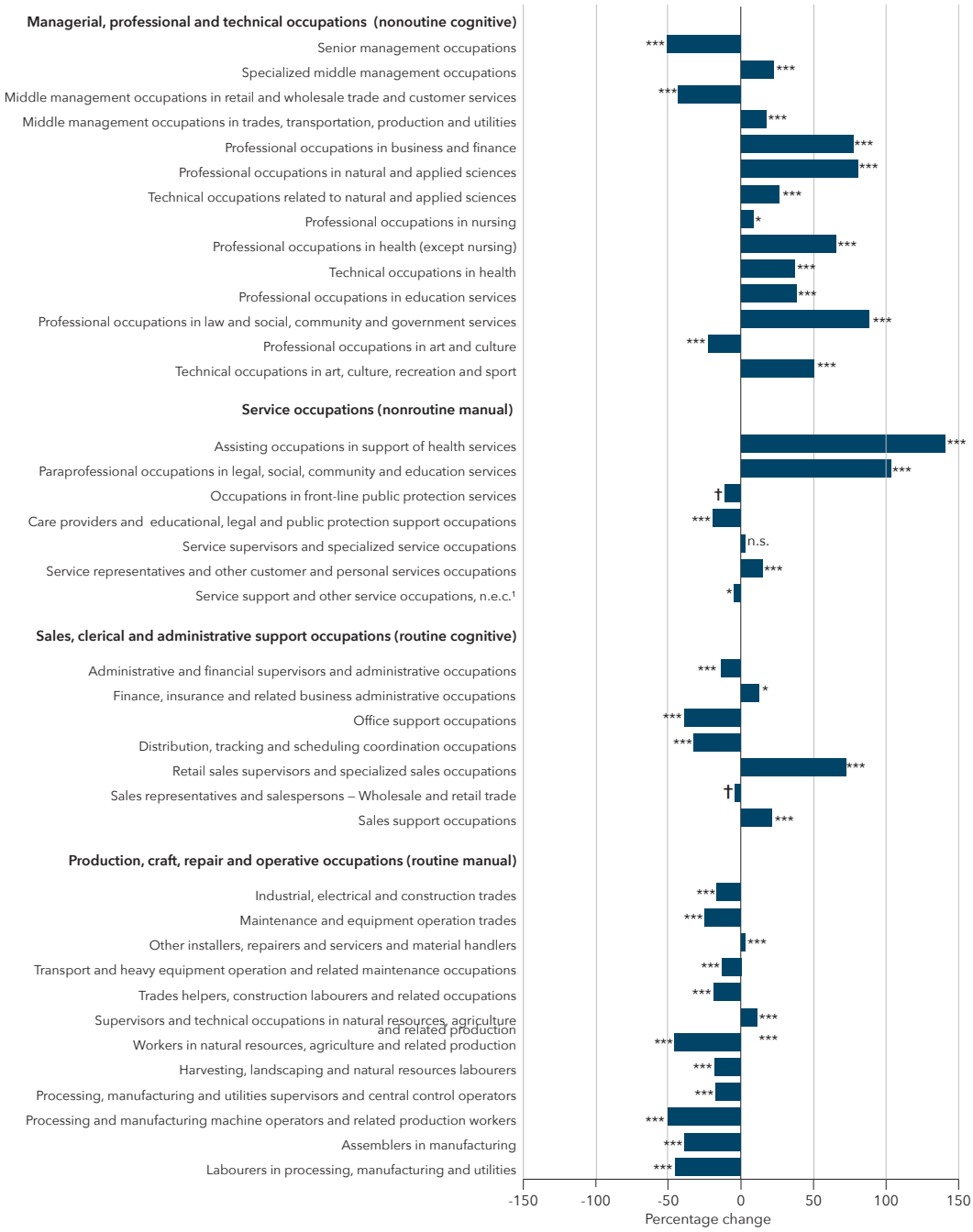
between 1987 and 2018 (a 9.1 percent decrease, figure 3). Nevertheless, this occupational-task group still accounted for the second highest share of workers in 2018 (24.9 percent, figure 2).

To summarize, over the past three decades, employment gradually shifted from occupations involving routine tasks to those involving nonroutine tasks. However, these trends were no more evident in the last decade than in the past. The changes in the employment shares of occupational-task groups between 2011 and 2018 were small. For example, management, professional and technical occupations (nonroutine cognitive tasks) saw the largest shift, with an increase of 1.8 percentage points.

Looking at trends in employment shares by major occupational group provides further context for these findings (figure 4).[20] The majority of occupations associated with nonroutine tasks saw their employment share rise, with the largest increases observed in two service occupations (manual tasks). Assisting occupations in support of health services rose 140.9 percent and paraprofessional occupations in legal, social,

[20] In the 2011 NOC, major groups represent the broad occupational category and skill level of an occupation. NOC skill levels are a broad aggregation of education, training and work experience that accounts for the complexity of job tasks and responsibilities associated with an occupation. For example, professional occupations in nursing is a major group that includes two minor occupational groups: registered nurses and nursing coordinators and supervisors. The 2011 NOC indicates major occupational groups using a two-digit code.

Figure 4. Change in employment shares by occupational group, Canada, 1987-2018 (percent)



Source: Authors' calculations based on Statistics Canada, Labour Force Survey (1987 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701.
[1] n.e.c. = not elsewhere classified.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, † $p < 0.10$, n.s. = not statistically significant

community and education services increased by 103.5 percent. Among managerial, professional and technical occupations (cognitive tasks), the largest increase in employment shares occurred in professional occupations in law and social, community and government services, which rose by 88.4 percent, and those in natural and applied sciences, which increased by 80.8 percent. There were two noteworthy exceptions within managerial, professional and technical, and service occupations. The employment share of senior management occupations fell by 50.9 percent and those of middle management occupations in retail and wholesale trade and customer services declined by 43.2 percent.

Employment shares decreased in most occupations involving routine tasks. The largest declines occurred for processing, manufacturing machine operators and related production workers (by 50.4 percent) and workers in natural resources, agriculture and related production (by 45.8 percent). The share of office support occupations dropped by 39 per cent, and the share of distribution, tracking and scheduling coordination occupations fell by 32.5 percent. At the same time, the share of workers employed as retail sales supervisors and in specialized sales occupations increased by 72.3 percent and that in sales support occupations by 21.4 percent.

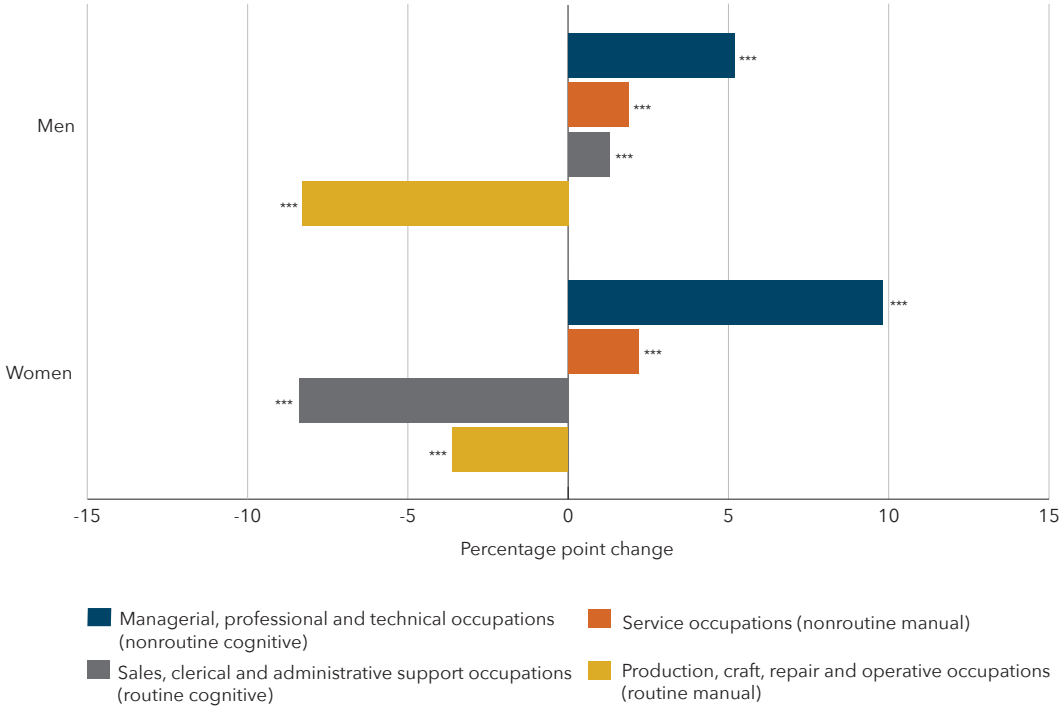
These findings mean that the employment shifts observed between 1987 and 2018 occurred across all occupations within task groups, with few exceptions, rather than being driven by one or two major occupations experiencing substantial growth.

TRENDS IN EMPLOYMENT SHARES BY GENDER, AGE GROUP AND LEVEL OF EDUCATION

For policy-makers, it is important to know whether the employment trends observed over the past three decades have affected various categories of workers differently. Analysis of trends in employment shares by occupation task group based on worker characteristics show that the most striking differences in employment shifts are those between men and women (figure 5). First, women's share in management, professional, and technical occupations (nonroutine cognitive tasks), grew by 9.8 percentage points, compared to a gain of 5.2 percentage points for men. Over the same period, the share of workers employed in production, craft, repair and operative occupations (routine manual tasks) declined, albeit less so among women (3.6 percentage points) than men (8.3 percentage points).[21] Finally, women's employment share in sales, clerical and administrative support occupations (routine cognitive tasks) decreased by 8.4 percentage points, whereas it increased by 1.3 percentage points for men.

[21] The difference between men and women was statistically significant at $p < 0.001$.

Figure 5. Change in employment shares by occupational-task group and gender, Canada, 1987-2018 (percentage points)



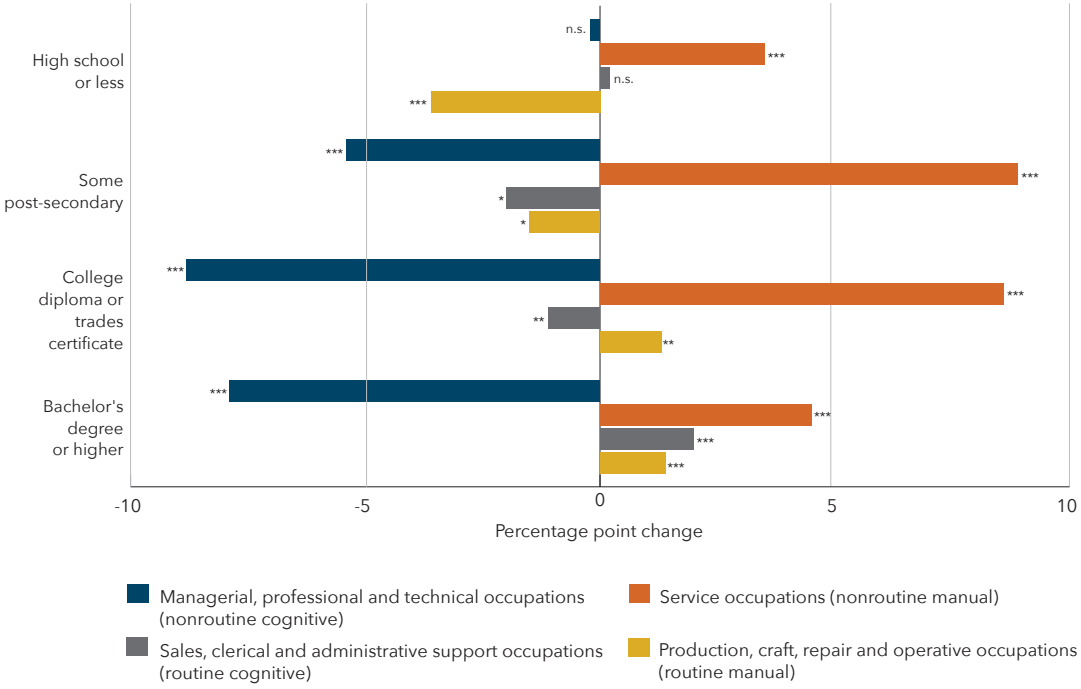
Source: Calculations by the authors based on data from Statistics Canada, Labour Force Survey (1987 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, n.s. = not statistically significant

Employment shifts across education groups are also interesting (figure 6).[22] At first glance, employment shares in managerial, professional and technical occupations (nonroutine cognitive tasks) fell for almost all post-secondary education groups, with the largest declines among workers with college diplomas or trades certificates (by 8.8 percentage points) and workers with university degrees (by 7.9 percentage points). This finding seems to conflict with the overall increase in the share of employment in managerial occupations shown in figure 2. But the explanation lies in the significant increase in the proportion of Canadians with postsecondary education over the past few decades. Whereas just over one in eight paid workers had a university degree in 1990 (13.1 percent), the ratio climbed to nearly three in ten by 2018 (29.1 percent).[23] While this increase in educational attainment led to a larger number of university-educated workers employed in managerial and other related occupations, the share of university graduates employed in managerial occupations may have fallen because other workers with degrees entered lower-skill occupations (Acemoglu and Autor 2010). As figure 6 shows, there has

[22] The analyses start in 1990 rather than in 1987 due to availability of consistent data on workers' education.
[23] These figures are based on a sample of all paid workers in the LFS regardless of age. Although many younger workers were not likely done with their schooling, they were nonetheless included in the sample to match the analytical sample in the rest of the study. Among those aged 25 or older, 16 percent of workers had a university degree in 1990, compared to 33.3 percent in 2018.

been an increase in employment shares among university graduates in all three remaining occupational-task groups. And in the case of sales, clerical and administrative support occupations (routine cognitive tasks), this increase coincided with a decline in the shares of workers with some post-secondary education, and college diplomas or trades certificates. The share of workers with post-secondary credentials also went up in production, craft, repair and operative occupations.

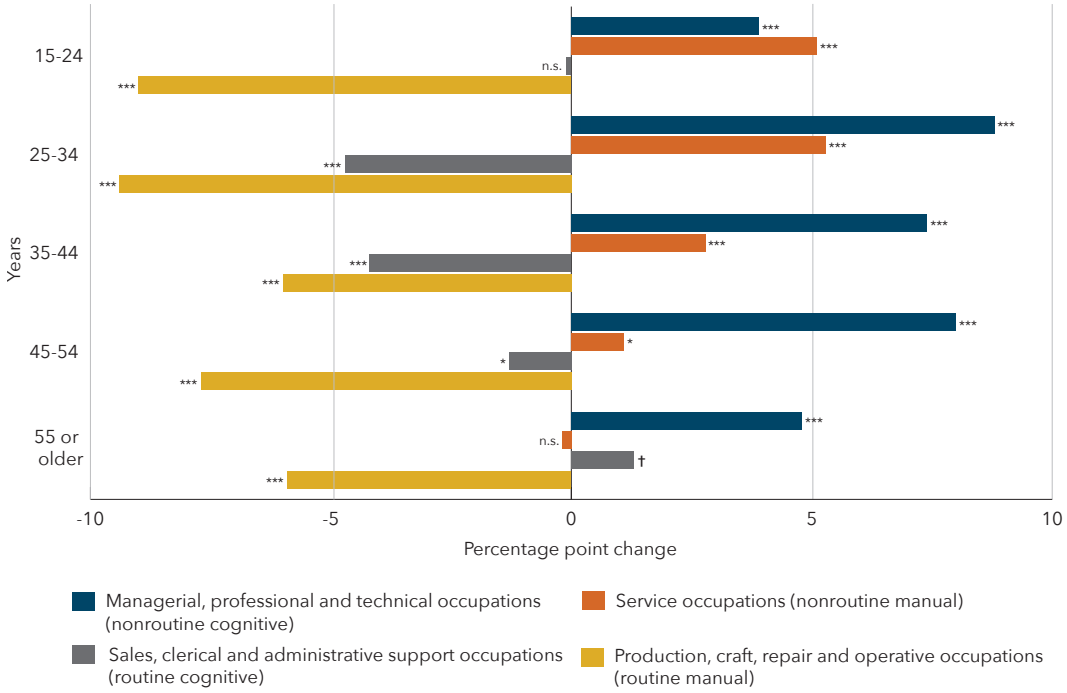
Figure 6. Change in employment shares by occupational-task group and level of education, Canada, 1990-2018 (percentage points)



Source: Authors' calculations based on Statistics Canada, Labour Force Survey (1990 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701.
Note: The years before 1990 were excluded because the education categories in the Labour Force Survey are not consistent before 1990.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, n.s. = not statistically significant

Changes in employment shares by age group repeat the patterns shown in figure 2, with occupations involving nonroutine tasks (either cognitive or manual) being on the rise, and occupations with routine tasks in decline (figure 7). The same patterns are observed for all age groups, except for older workers aged 55 or more, whose share of employment in sales, clerical and administrative support occupations and service occupations has not changed.

Figure 7. Change in employment shares by occupational-task group and age, Canada, 1987-2018 (percentage points)



Source: Authors' calculations based on Statistics Canada, Labour Force Survey (1987 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, †$p < 0.10$, n.s. = not statistically significant

THE NATURE OF WORK AND CHANGES IN THE INDUSTRIAL STRUCTURE

Employment shifts may be caused by changes in the industrial structure due to the changing demand for products and services, and not just by technology-driven changes in the demand for skills. It is worth taking a second look at occupational shifts to verify if the changing industrial structure indeed drives the results.

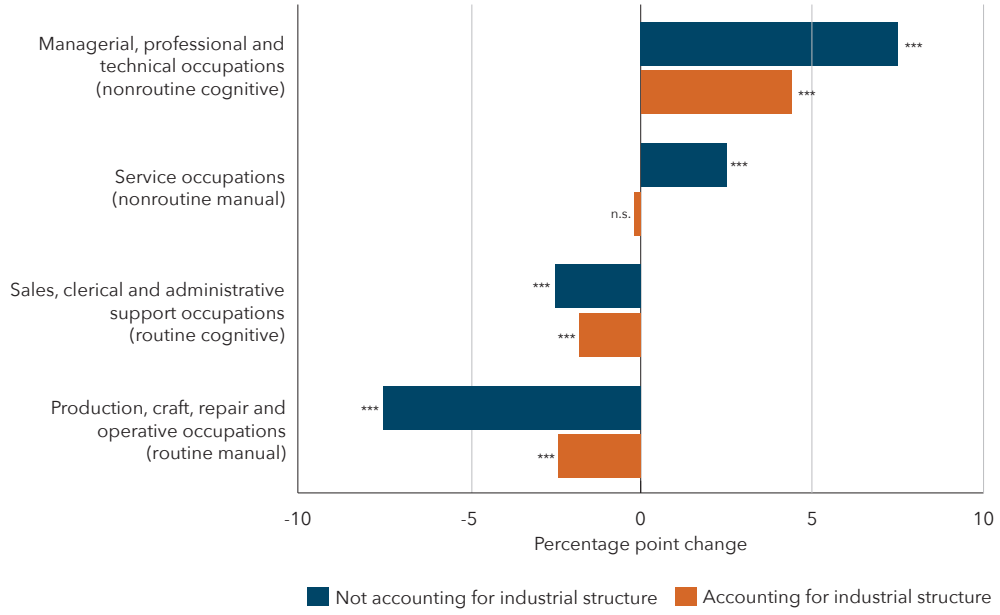
Regressions were estimated separately for each of the four occupational-task groups, taking into account the share of employment in 1987 and 2018 in the industries to which the occupations in question belonged. If these analyses reveal that, after accounting for employment shares in various industries, the magnitudes of employment shifts across occupational groups become smaller, then at least a portion of these shifts can be attributed to the changing industrial structure of the economy.

The results suggest that changes in Canada's industrial structure were indeed responsible for at least some of the observed shifts in employment shares across

occupational-task groups (figure 8).[24] First, the increase in the employment share in service occupations reported earlier appears to be fully driven by the growing share of Canadians employed in the service sector, especially in health services. As figure 4 showed earlier, there was also a large increase in the share of workers employed in paraprofessional occupations in legal, social, community and education services between 1987 and 2018.

Second, about two-thirds of the decrease in the employment share in production, craft, repair and operative occupations is attributable to a shift away from industries comprising jobs involving routine manual tasks. This occurred mostly in manufacturing, where the share of paid employees decreased from 17.8 in 1987 to 10.2 percent in 2018 in the analytical sample used in the study. [25] Nevertheless, the remaining third of this shift that cannot be attributed to the changing industrial structure is still statistically significant.

Figure 8. Change in employment shares by occupational-task group before and after accounting for industrial stucture, Canada, 1987-2018 (percentage points)



Source: Authors' calculations based on Statistics Canada, Labour Force Survey, https://www.statcan.gc.ca/eng/survey/household/3701.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, ł $p < 0.10$, n.s. = not statistically significant

[24] Please refer to Frank, Yang and Frenette (2021) for more information about the methodology.
[25] Both automation and offshoring play important roles in the decline of manufacturing jobs with a high intensity of routine tasks (Muro, Maxim and Whiton 2019). Offshoring of the manufacturing sector had contributed to the shift of workers away from manufacturing jobs into occupations in other sectors (Cheung, Rossiter and Zheng 2008).

Third, industrial shifts also drive some of the changes in the employment share in occupations with a high intensity of cognitive tasks. They explain 40 percent of the increase in management, professional and technical occupations and 25 percent of the decrease in sales, clerical and administrative support occupations.

A similar exercise was repeated for each of the 16 task variables for 2011-18.[26] The estimated changes in the average importance of these 16 tasks remain statistically significant at the 5 percent level, even though accounting for industrial shifts reduced the magnitude of changes across most work tasks.

WHAT DOES THE EVIDENCE REVEAL SO FAR?

Ongoing concerns about the changing nature of work have increasingly focused on the degree to which automation affects workers in Canada and worldwide. Recent developments in artificial intelligence have added to these concerns, given the prospect of increasingly complex tasks being automated. Hence, the perceived unprecedented pace and extent of change in the nature of work have caught the attention of scholars and policy-makers. Recent research conducted at Statistics Canada sought to find evidence on the degree to which the nature of work in Canada has been changing, focusing in particular on what has been happening in the last decade in a context of rapid advances in artificial intelligence.

The "nature of work" refers to both the mix of tasks (work activities) that workers do on the job and the mix of jobs at the workforce level. The study focused on trends between 2011 and 2018 in employment shares of specific task groups: mainly routine or nonroutine, and mainly cognitive or manual.

The results suggest that, during the last decade, the average importance of most nonroutine cognitive analytical and interpersonal tasks, which are complementary to automation, gained importance, although these gains were moderate. The evidence is less clear on manual tasks, routine and nonroutine, that could conceivably be automated. The magnitude of changes in the importance of these tasks was generally quite small. Overall, the results suggest that automation technologies may have affected workers' tasks in recent years, though not substantially. Hence, it may be too early to declare that the nature of work has changed, at least in terms of tasks performed on the job. Nevertheless, the results provide valuable insight into which work tasks are likely to continue to increase in importance in the future as new technologies become available and are further integrated into the workplace.

To provide context and a longer-term perspective, the study also examined changes in the share of employment across various occupational-task groups and occupations since 1987. This analysis showed that the shifts in employment observed in the past decade were a continuation of trends observed in recent decades. In other words,

[26] These results are available upon request.

even with the appearance of conceptually new technologies, increases in employment shares in nonroutine occupations were no more pronounced in the last decade than in the past.

Despite important changes taking place in the Canadian economy since 1987, employment shares shifted rather gradually across occupational-task groups from occupations that entail primarily routine tasks to those centred on nonroutine tasks. The shares of Canadians working in managerial, professional and technical occupations (nonroutine cognitive tasks) and service occupations (nonroutine manual tasks) increased. The shares of workers employed in production, craft, repair and operative occupations (routine manual tasks) and in sales, clerical and administrative support (routine cognitive tasks) decreased over this period.

This gradual shift was generally observed across most sociodemographic groups, with some exceptions. For example, women became less likely to work in jobs associated with routine cognitive tasks, whereas men became more likely to be employed in these jobs. Additionally, while employment share increases in nonroutine occupations were observed across most age groups, the share of older workers remained unchanged in jobs associated with nonroutine manual tasks. It increased, though only marginally, in jobs associated with routine cognitive tasks. Finally, despite an overall increase in the share of workers in managerial, professional and technical occupations associated with nonroutine cognitive tasks, decreased employment shares were observed for workers with post-secondary education.

While there is evidence that having a university education generally reduces a worker's risk of job transformation due to automation, the significant increase in the proportion of workers with post-secondary education over the past three decades resulted in some of these workers moving into jobs for which they may be overqualified. Consequently, these workers may be more affected by automation technology than their counterparts working in occupations requiring a university degree. Further investigation of the distribution of workers with post-secondary education across different occupational groups could provide greater insight into the extent to which these workers could be affected by changes in the nature of work.

The changing demand for skills due to new technologies, however, is not the only driving force behind these employment shifts. Changes in the industrial structure between 1987 and 2018 largely explain the increase in employment share in service occupations, about two-thirds of the decrease in production, craft, repair and operative occupations, and roughly 40 percent of the increase in managerial, professional and technical occupations. Nevertheless, changes in the average importance of various tasks investigated in the study remain significant even after accounting for the changes in industrial structure.

Understanding the consequences of automation cannot be complete without close monitoring of the evolution of work, both for individual occupations and for the workforce as a whole. The results in this study provide the first insights into the skills

that workers may require to succeed as automation technology becomes more widespread across industries and occupations. Some authors suggest that the job tasks of many workers may now require a greater degree of technological literacy in terms of skills such as operating a computer, using e-mail, navigating websites or awareness of data security issues (Walker, Bowkett and Duchaine 2018). However, this does not necessarily mean that every worker must have advanced technical skills such as mastery of programming languages. Rather, the development of foundational skills, such as complex problem-solving skills, can enable workers to adapt to the changing nature of work and provide them with the capacity to incorporate new technologies into their work activities (Levy and Murnane 2013; Walker, Bowkett and Duchaine 2018).

Events such as the COVID-19 pandemic may spur employers to adopt automation technology more quickly than they would have otherwise, making some tasks more prevalent than others. The exact nature and extent of these changes in response to the pandemic remain to be seen. Nonetheless, it is increasingly important to monitor how Canadian jobs evolve as technological advances enable more tasks to be automated.

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APPENDIX

Table A1. Mean importance scores of occupational tasks, Canada, 2011 and 2018

	Mean score	
	2011	2018
Nonroutine cognitive – analytical		
Analyzing data or information	3.018	3.119
Thinking creatively	3.090	3.163
Interpreting the meaning of information for others	3.014	3.098
Nonroutine cognitive – interpersonal		
Establishing and maintaining interpersonal relationships	3.651	3.701
Guiding, directing and motivating subordinates	2.700	2.792
Coaching and developing others	2.856	2.956
Routine cognitive		
Structured versus unstructured work	3.924	3.944
Importance of repeating the same tasks	3.290	3.331
Importance of being exact or accurate	4.072	4.130
Routine manual		
Pace determined by speed of equipment	1.920	1.881
Controlling machines and processes	2.520	2.552
Spend time making repetitive motions (frequency)	3.149	3.162
Nonroutine manual/physical		
Operating vehicles, mechanized devices or equipment	2.267	2.254
Spend time using hands to handle, control or feed objects, tools or controls (frequency)	3.309	3.287
Spatial orientation	1.495	1.499
Manual dexterity	2.441	2.408

Sources: Authors' calculations based on Statistics Canada, Labour Force Survey (2011 and 2018), https://www.statcan.gc.ca/eng/survey/household/3701; US Department of Labor, O*NET (2011 and 2018), https://www.onetonline.org.
Notes: The importance scale comes from the O*NET system. For all but three occupational tasks, the importance scores range from 1 (not important) to 5 (extremely important). The exceptions are "structured versus unstructured work," which is measured on a scale ranging from 1 (no freedom) to 5 (a lot of freedom); and "spend time making repetitive motions" and "spend time using hands to handle, control or feed objects, tools or controls," which are based on a frequency scale ranging from 1 (never) to 5 (continually or almost continually). The percentage change was calculated using multiple regressions.

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