THE AUTOMATION POTENTIAL OF THE BRITISH COLUMBIA LABOUR MARKET

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OCTOBER 2018

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WHERE LEADERS MEET TO UNLOCK B.C.'S FULL POTENTIAL

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TABLE OF CONTENTS

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HIGHLIGHTS

- Labour's role in the economy is changing. Technologies can perform an ever-expanding range of tasks in the production of goods and services.

- About 42% of B.C. jobs are in occupations with high potential for automation in the next 10 to 20 years, from a technical capabilities standpoint.

- B.C. has a slightly greater share of jobs in highly-automatable occupations compared to Canada and could therefore face more adjustment costs. Low-income workers could bear a disproportionate share of these costs. Automation could also exacerbate B.C.'s negative employment income gap relative to Canada, all else being equal.

- More than half of B.C. jobs are in "sales and service," "business, finance and administration" and "trades, transport and equipment operators" occupations that are highly automatable, on average.

- About 90% of B.C. jobs are in occupations where at least 10% of tasks can be automated by a current technology. About 35% of jobs are in occupations where at least 50% of tasks are automatable. And about 11% of jobs are in occupations where 80% or more of the tasks are automatable.

- There is much uncertainty about the pace of digital innovation, adoption and transformation across the economy. This study is a technically-focused risk assessment only. The actual pace and extent of automation will depend on non-technical factors as well, including economic, social and regulatory developments. Furthermore, productivity gains and the creation of new roles for labour could more than offset automation's effects on overall labour demand.

Come gather 'round people
Wherever you roam
And admit that the waters
Around you have grown
And accept it that soon
You'll be drenched to the bone.
If your time to you
Is worth savin'
Then you better start swimmin'
Or you'll sink like a stone
For the times they are a-changin'.

Bob Dylan,
The Times They Are a-Changin', 1964

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1. INTRODUCTION

"The Times They Are A-Changin'," song-writer Bob Dylan wrote indelibly in 1964. The waters of technological change are rising for many workers in the global labour market. Technologies can perform an ever-expanding range of tasks in the production of many goods and services. There will be economic opportunities and adjustment costs as labour's role in the production process and the overall economy changes.

How will digitalization impact the British Columbia labour market? We attempt to answer one aspect of that question.[1] We examine the labour-substitution (i.e. automation) potential of occupations and tasks in the B.C. and Canadian labour markets from a technical capabilities standpoint. Our estimates are based on two prominent U.S. studies, Frey and Osbourne (2017) and Chui et al. (2015), adapted to the Canadian context by Lamb (2016). Here, we update and extend the analysis for B.C. using 2016 Canadian Census data.

This study is a risk assessment only. Our findings highlight the scope and distribution of automation-related adjustment costs that *could* lie ahead for the province. These costs could take the form of re-skilling, re-tasking, relocation or lower real wage growth for workers performing automatable occupations and tasks. Policy-makers, firms and workers will need to carefully manage these challenges.

Technologies can perform an ever-expanding range of tasks in the production of many goods and services. There will be economic opportunities and adjustment costs as labour's role in the production process and the overall economy changes.

The *actual* pace and extent of automation will depend on many non-technical factors as well. These include labour supply and demand developments, relative factor prices, consumer prices and preferences, regulatory and social acceptance of new technologies, and unforeseeable engineering breakthroughs. More broadly, technological progress raises productivity and creates new roles for labour. These positive impacts could more than offset labour substitution effects on total labour demand.

The paper is structured as follows. Section 2 provides a brief summary of the two methodologies. Section 3 presents the results on automation potential by occupation based on Frey and Osbourne's (2017) methodology. Section 4 presents the results on automation potential by task based on Chui et al.'s (2015) alternative methodology. Section 5 profiles some of B.C.'s most common occupations. Section 6 discusses some policy implications. Section 7 explains the two methodologies in more detail. Section 8 discusses the limitations of our study. Section 9 concludes.

[1] A short summary of this paper is available as Williams 2018a. To read more on the broader impacts of digitalization, see Berger and Frey (2016), Bughin et al. (2017), D'Souza and Williams (2017), Oschinski, and Wyonch (2017), Carney (2018) and Nedelkoska and Quintini (2018). Previous BCBC publications exploring this topic in the Canadian and B.C. context include St Laurent (2017), Williams (2018b) and Williams (2018c).

TABLE 1: **BOTTLENECKS TO AUTOMATION**

Computerization bottleneck	O*NET variable	O*NET description
Perception and manipulation	**Finger dexterity**	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
	Manual dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
	Cramped spaces	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Creative intelligence	**Originality**	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
	Fine Arts	Knowledge of theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
Social intelligence	**Social perceptiveness**	Being aware of others' reactions and understanding why they react as they do.
	Negotiation	Bringing others together and trying to reconcile differences.
	Persuasion	Persuading others to change their minds or behavior.
	Assisting and caring	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patient.

Source: Wallace-Stephens 2017, adapted from Frey and Osbourne (2017).

2. METHODOLOGY IN BRIEF

Our main approach is based on a widely-cited study by Frey and Osbourne (2017). They explore the technical feasibility of automating occupations using a computer-based technology during the next 10-20 years. Automation depends on an occupation's task structure and the prevalence of engineering bottlenecks to computerization. The bottlenecks correspond to descriptive variables about occupations contained in the O*NET labour market database (**Table 1**).[2]

The intuition is as follows. Technologies are becoming increasingly capable of performing activities that involve basic social interactions and routine, repetitive or rule-based tasks. Occupations featuring such tasks are susceptible to future automation. In other words, it will become technically possible to automate them. Firms will have a *choice* between using labour or capital to perform the task. For example, cashiers, cooks, paralegals and truck drivers have a relatively high probability of automation over the long term (even though in today's economy, there are job openings for such positions in B.C. and many other jurisdictions).

In contrast, technologies are unable, and are unlikely to soon become able, to perform certain other human activities. These activities tend to involve: *perception and manipulation* (finger dexterity, manual dexterity, and working in cramped spaces), *creative intelligence* (originality and problem solving, fine arts) and *social intelligence* (social perceptiveness, negotiation, persuasion, and assisting and caring for others). Engineering bottlenecks associated with these activities are unlikely to be overcome in the next 10-20 years. Therefore, occupations with tasks requiring these skills have a lower probability of automation. Examples include teachers, lawyers, general practitioners, civil engineers, and restaurant and food service managers.

[2] O*NET is the United States' primary database for occupational information. The database contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy.

Our second approach is based on another study by Chui et al. (2015). They estimate the potential to automate tasks within occupations using existing technologies. Their approach provides a way of thinking about the near-term potential to automate *parts* of occupations. Unlike Frey and Osbourne (2017), the approach does not consider future engineering developments, only the technical capabilities of current technologies. Again, the focus is solely on technical feasibility, rather than on the broader set of factors that determine the pace and extent of automation in the labour market.

3. RESULTS — AUTOMATION OF OCCUPATIONS

Overall Results

We find that 42% of B.C. workers are in occupations that have a high probability of being automated over the next 10-20 years (**Figure 1**).[3] Another 21% of workers are in occupations that have a moderate probability of long-term automation, while 37% of workers are in occupations with a low probability of automation. We define these long-term probability or risk regions as "high" (≥70% probability), "moderate" (30-69% probability) and "low" (<30% probability).

How does B.C. compare to Canada? Canada has 41% of total employment in the high probability region, 22% in the moderate region and 37% in the low region (**Figure 2**). B.C. therefore has a slightly greater share of jobs at high risk, and a slightly lower share of jobs deemed to be at moderate risk.[4]

Results by Major Occupational Group

Next, we present the analysis according to the ten major occupational groups, also known as one-digit National Occupational Classification (NOC) codes. Most B.C. jobs today (i.e. 77%) are concentrated in five types of occupations (**Figure 3**). The top three groups – making up 54% of total employment – have the highest average probability of long-term automation. They are occupations in: "sales and service" (24% of total B.C. employment); "business, finance and administration" (15% of employment); and "trades, transport and equipment operators" (15% of employment). The next two most important groups have the lowest average automation prospects: "management" (12% of employment); and "education, law and social, community and government services" (11% of employment). Meanwhile, the five remaining groups make up just 23% of provincial employment.

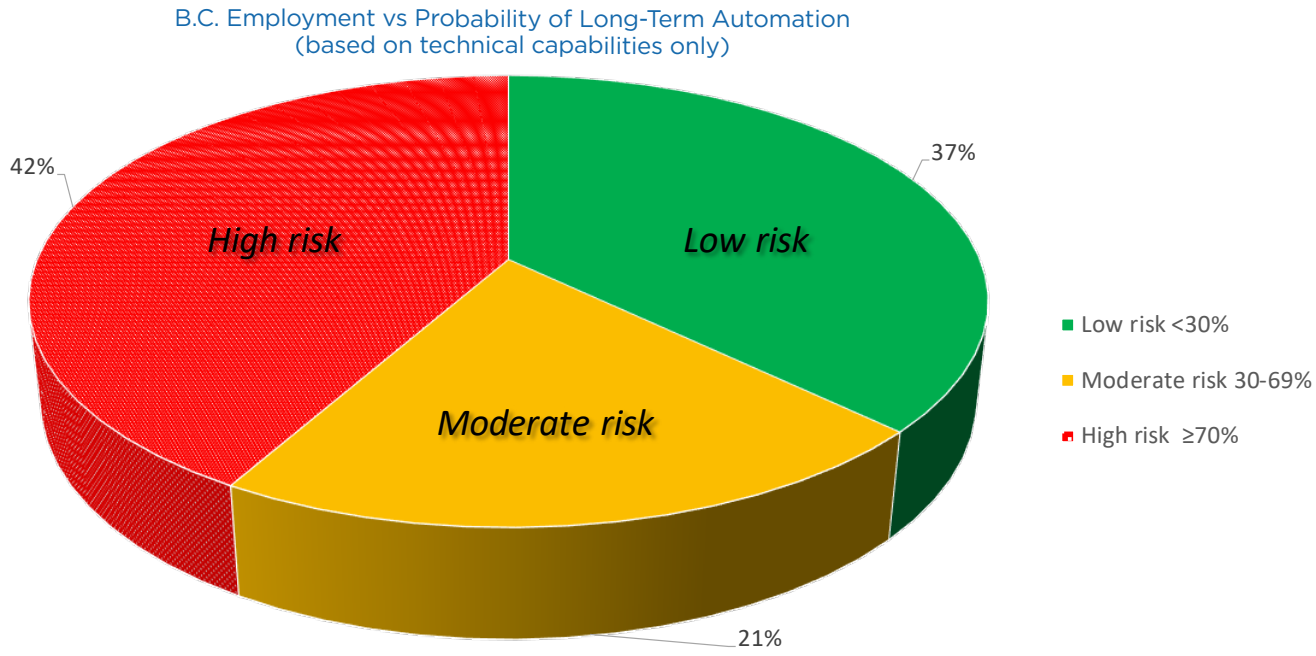
How do B.C. and Canada compare across the ten major occupational groups (**Figure 4**)? B.C. has a larger share of employment in groups that have high average automation prospects. Also, the types of jobs found within the major occupation groups in B.C. tend to have higher average prospects for automation than Canada. The analysis therefore suggests that B.C. could face more adjustment costs from automation than Canada over the next 10-20 years.

This can be demonstrated by looking at two groups that make up 40% of provincial employment. B.C. has a larger share of jobs in "sales and service" occupations with high potential for automation. For "business, finance and administration" occupations, B.C. and Canada have similar employment shares, but the types of jobs found in B.C. are, on average, more susceptible to automation.

Technologies are increasingly capable of performing routine, repetitive and rules-based tasks, as well as tasks requiring simple social interactions. Occupations featuring these sorts of tasks have a high probability of automation over the next 10-20 years.

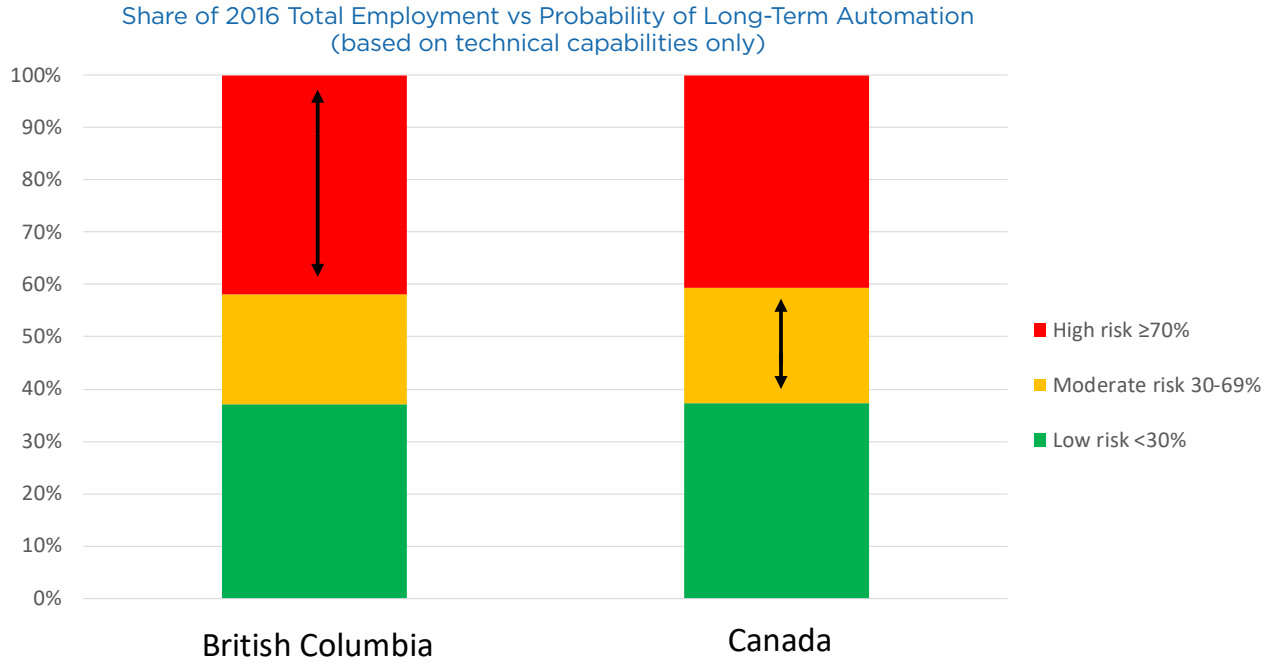
[3] The results in Section 3 are based on the analytical approach developed by Frey and Osbourne (2017) and adapted for the Canadian context by Lamb (2016).
[4] Using 2011 data for Canada, Lamb (2016) found 42% of jobs at high risk, 22% of jobs at moderate risk and 36% at low risk. Our analysis therefore suggests that automation risks for Canada decreased slightly between 2011 and 2016 (in 2016, about 31,000 fewer jobs are in the high-risk category).

FIGURE 1: **B.C. EMPLOYMENT IS CONCENTRATED IN OCCUPATIONS WITH HIGH AND LOW PROSPECTS FOR AUTOMATION**



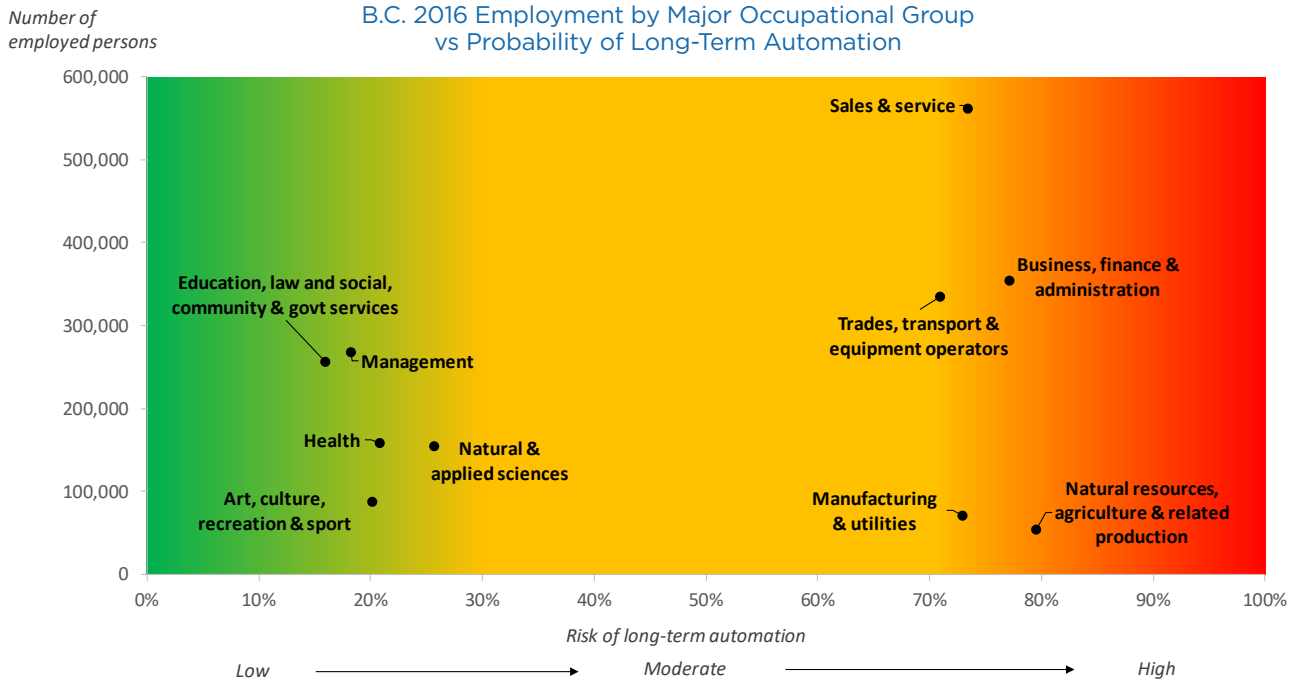
Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

FIGURE 2: **B.C. HAS A SLIGHTLY GREATER SHARE OF JOBS IN OCCUPATIONS WITH HIGH PROSPECTS FOR AUTOMATION**



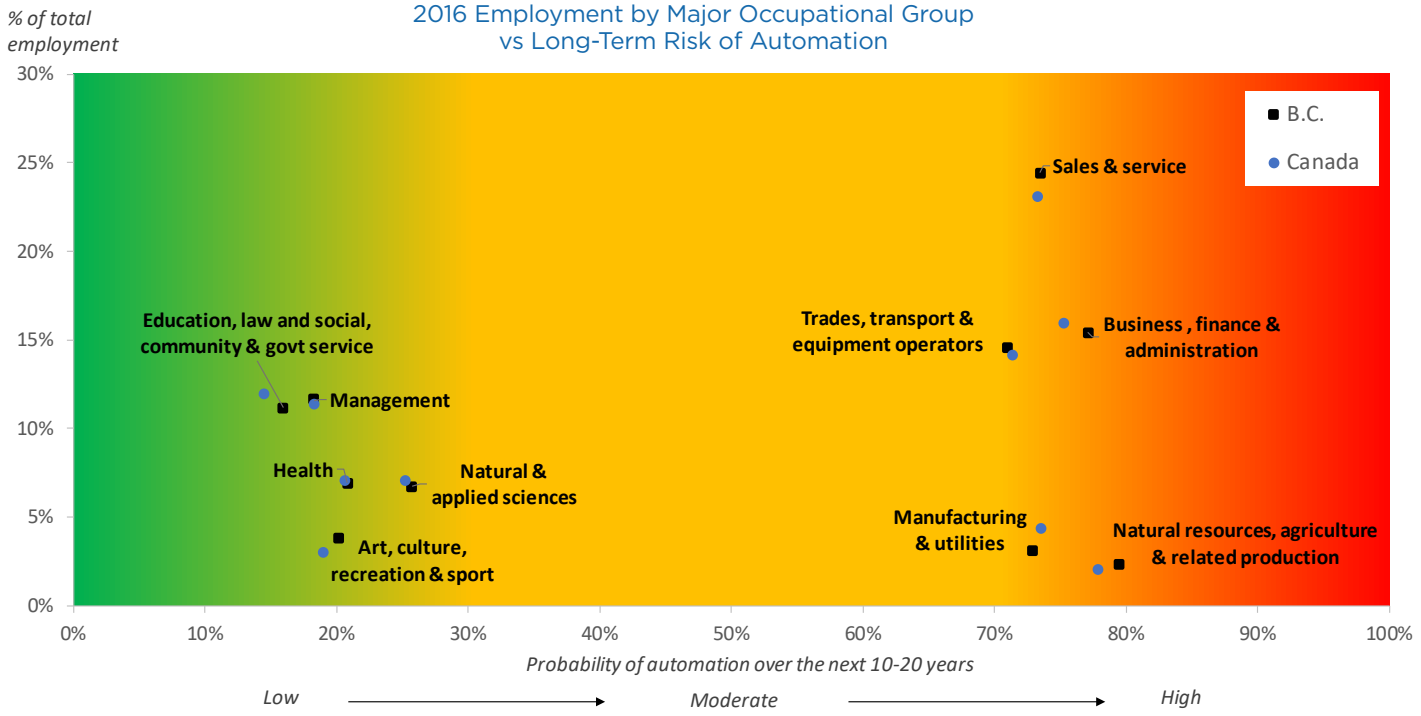
Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

FIGURE 3: **B.C.'S MAJOR OCCUPATIONAL GROUPS WILL COMPETE WITH TECHNOLOGY TO DIFFERENT DEGREES**



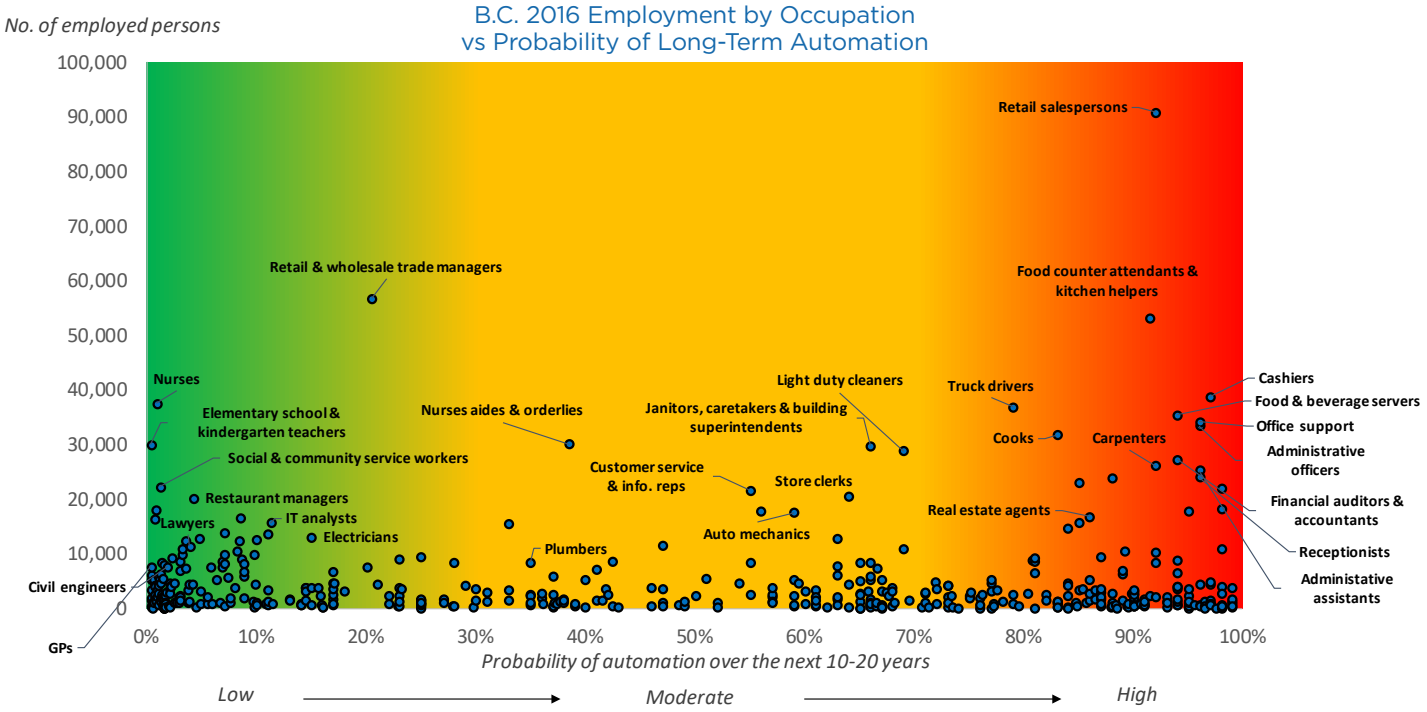
Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

FIGURE 4: **B.C.'S MAJOR OCCUPATIONAL GROUPS ARE SLIGHTLY MORE EXPOSED TO AUTOMATION THAN CANADA**



Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

FIGURE 5: **B.C. EMPLOYMENT IS CLUSTERED IN OCCUPATIONS WITH HIGH AND LOW POTENTIAL FOR AUTOMATION**



Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

Results by Individual Occupation

Figure 5 presents the results for 499 individual occupations (i.e. four-digit NOCs).[5] Most B.C. occupations are clustered in the high and low probability ranges. Some noteworthy occupations are separately identified.

From a technical standpoint, technologies are increasingly capable of performing routine, repetitive and rules-based tasks, and tasks requiring simple social interactions. Occupations featuring these sorts of tasks have a high probability of automation over the next 10-20 years. Examples include retail salespersons, food counter attendants, kitchen helpers and related occupations, cashiers, transport truck drivers, food and beverage servers, general office support workers, administrative offices and cooks.

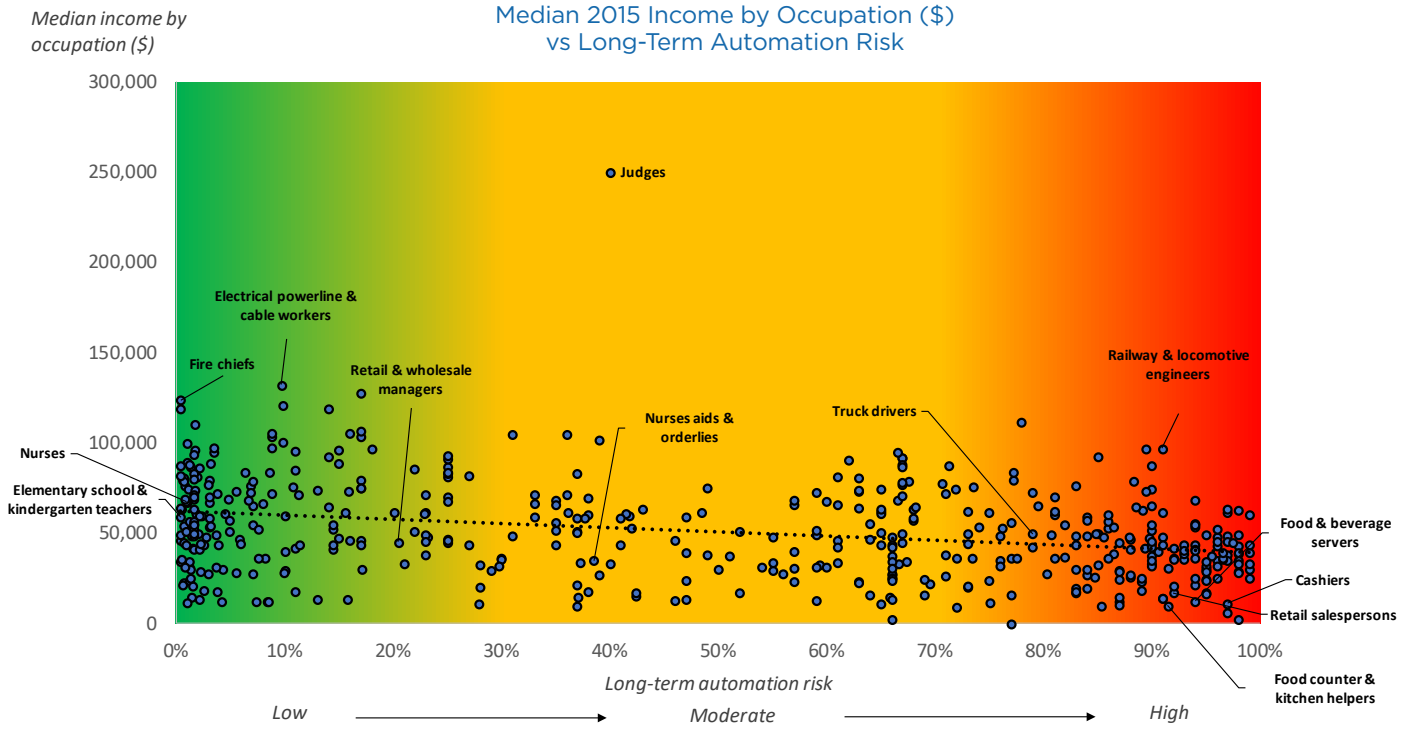
In contrast, occupations featuring tasks requiring perception and dexterity, creative intelligence and social intelligence will be difficult to automate. Examples include retail and wholesale trade managers, nurses, elementary school and kindergarten teachers, social and community service workers, restaurant and food service managers, and secondary school teachers.

Results by Median Occupational Income

Figure 6 plots the median employment income for 499 individual occupations in B.C. against their long-term prospects for automation.[6,7] The possibility of being replaced by a labour-saving technology appears to be negatively related to median occupational income. Lower-income jobs with high automation potential include retail salespersons, food

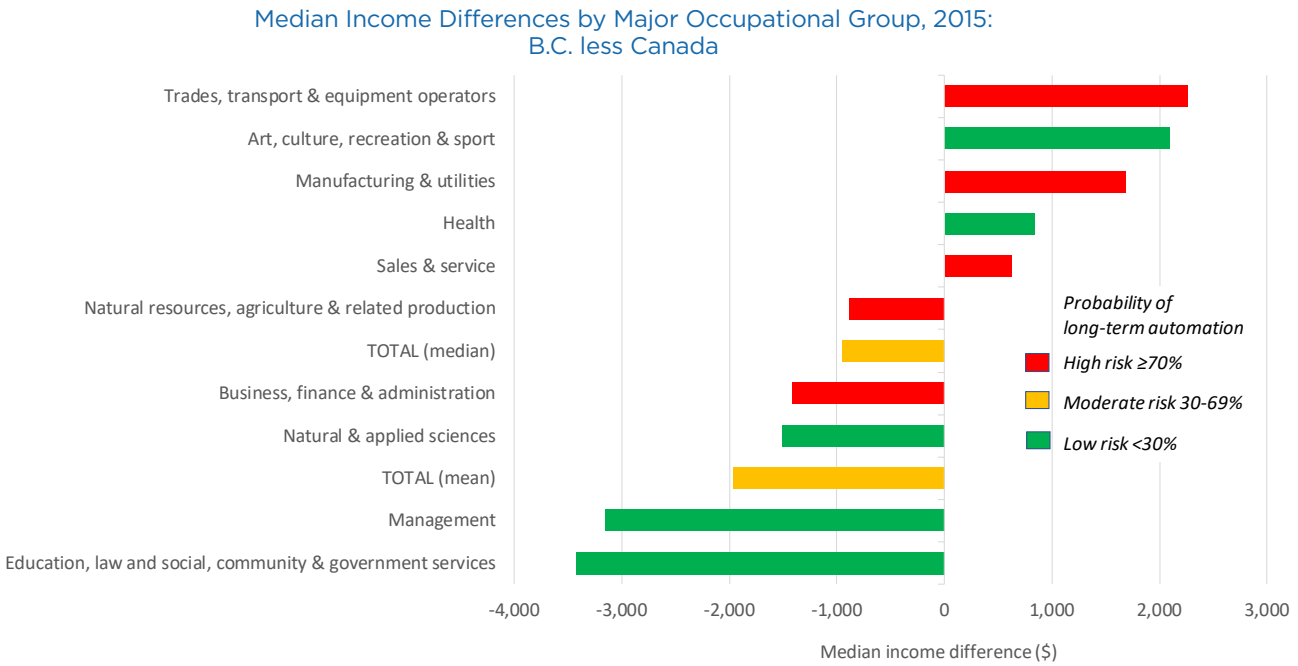
[5] There are 500 NOCs. We omit non-commissioned Canadian Armed Forces personnel from the analysis, leaving 499 individual occupations in our study.
[6] The 2016 Canadian Census provides data on incomes by occupation for calendar year 2015. Employment income is defined as all income received as wages, salaries and commissions from paid employment and net self-employment income from farm or non-farm unincorporated business and/or professional practice.
[7] A median takes the middle observation among a set of observations sorted from high to low. It is different from the mean. The mean is the sum of incomes divided by the number of observations. We use median incomes to avoid the possibility that the mean is overly influenced by just a few extreme high or low observations.

FIGURE 6: AUTOMATION RISKS ARE NEGATIVELY CORRELATED WITH OCCUPATIONAL INCOME



Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

FIGURE 7: AUTOMATION PRESSURES COULD EXACERBATE B.C.'S INCOME GAP WITH CANADA



Source: Frey and Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

counter attendants, kitchen helpers and related support occupations, cashiers, and food and beverage servers. Higher-income occupations with low automation potential include electrical power line and cable workers, nurses, teachers and fire chiefs.

How could automation affect employment incomes in B.C. relative to Canada? **Figure 7** and **Table 2** show the ten major occupational groups and the median income gaps between B.C. and Canada. Median incomes for B.C. workers are about $1,000 lower than Canada, while mean incomes are about $2,000 lower.

The analysis suggests that automation could see a widening of the income gap between B.C. and Canada. Occupational groups where B.C. currently has an income advantage – "sales and service," "trade, transport and equipment operators" and "manufacturing and utilities" occupations – face high risk of automation. These groups represent 42% of provincial employment. A further 18% of B.C. jobs are in "business, finance and administration" and "natural resources, agriculture and related production" occupations that face high automation risk (and also relative to Canada, see **Figure 4**) and have a negative income gap already.

TABLE 2: **B.C.'S MAJOR OCCUPATIONAL GROUPS HAVE VARYING EXPOSURES TO AUTOMATION**

B.C. Employment by Major Occupational Group

Occupation	Employed persons 2016 (persons)	Share of B.C. employment (%)	Median income 2015 ($)	Median income gap, B.C. less Canada ($)	Risk of long-term automation (Frey & Osbourne) (%)
Sales & service	561,800	24%	18,933	619	73%
Business, finance & administration	354,655	15%	40,310	-1,407	77%
Trades, transport & equipment operators	334,435	15%	44,647	2,268	71%
Management	268,155	12%	56,814	-3,147	18%
Education, law and social, community & government services	256,640	11%	40,723	-3,422	16%
Health	158,985	7%	47,506	837	21%
Natural & applied sciences	154,525	7%	64,702	-1,505	26%
Art, culture, recreation & sport	87,390	4%	20,772	2,099	20%
Manufacturing & utilities	71,425	3%	38,622	1,690	73%
Natural resources, agriculture & related production	53,915	2%	21,577	-881	79%
TOTAL	**2,301,925**	**100%**	**38,593**	**-949**	**52%**

Automation probabilities are classified as high ≥ 70% (red), moderate 30-69% (orange) and low <30% (green).

Source: Frey & Osbourne 2017, Lamb 2016, Statistics Canada, BCBC calculations.

4. RESULTS — AUTOMATION OF TASKS

The foregoing analysis was based on Frey and Osbourne's (2017) methodology. Their forward-looking approach focuses on the probability of engineering bottlenecks being overcome to make it technically possible to automate an occupation during the next 10-20 years. An alternative to this "top down," occupations-based approach is to take a "bottom up" view by focusing on the scope to automate individual tasks *within* occupations.

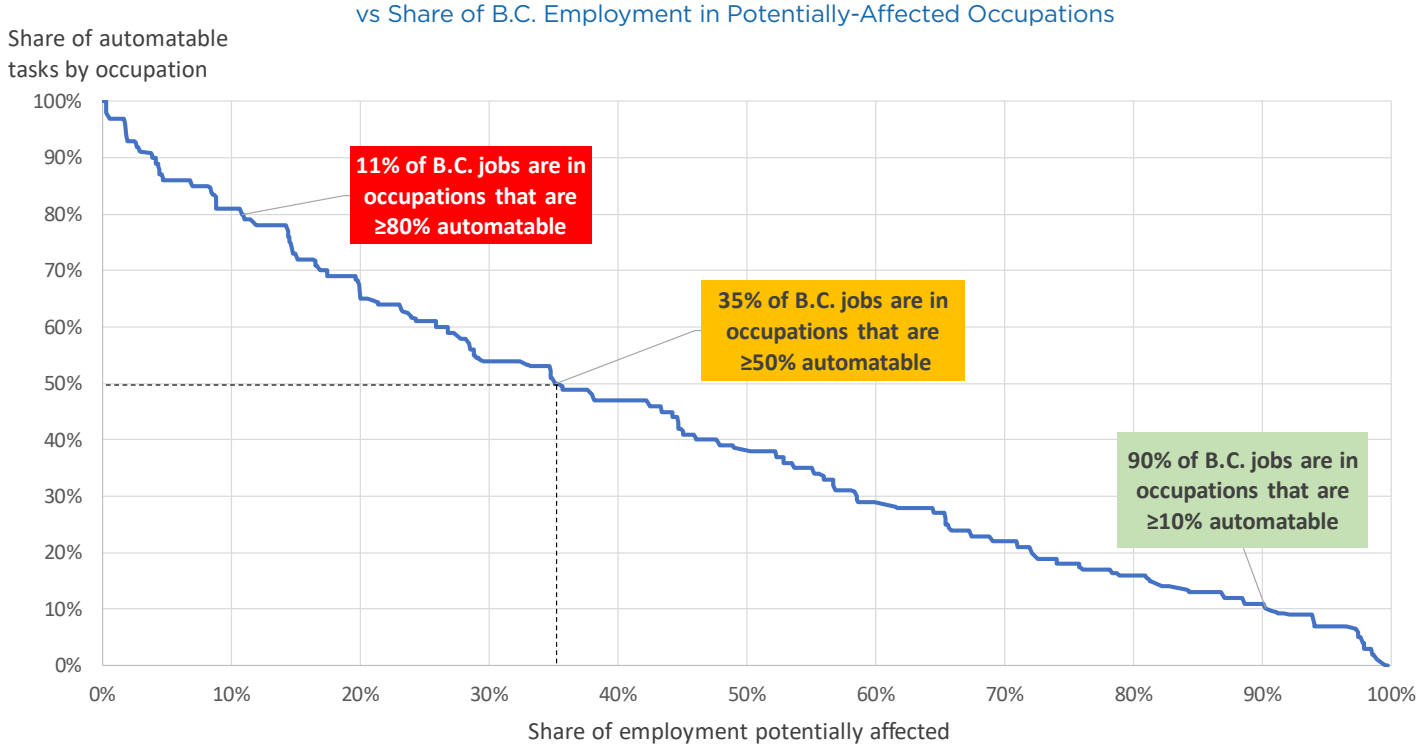
Chui et al. (2015) explore thousands of tasks within hundreds of occupations and ask whether they could be automated by an *existing* technology. Unlike Frey and Osbourne (2017), their approach does not consider future engineering developments but rather the technical capabilities of current technologies. It therefore provides a way of thinking about the *near-term* potential to automate *parts* of occupations.

We find that ninety percent of B.C. jobs are in occupations where at least 10% of the work tasks could be performed by a current technology (**Figure 8**). Thirty-five percent of B.C. jobs are in occupations where at least 50% of tasks are automatable. Eleven percent of jobs are in occupations where at least 80% of tasks are automatable.

Examples of occupations with high proportions of automatable tasks include bakers, foundry workers, machine operation and processing jobs in manufacturing operations, automotive service technicians, plasterers and drywallers, accounting clerks and bookkeepers. Examples of occupations where low proportions of tasks are automatable include massage therapists, management consultants, teachers, restaurant and food service managers, and university professors and lecturers.

FIGURE 8: **B.C. WORKERS FACE VARYING DEGREES OF POTENTIAL TASK AUTOMATION**

Share of an Occupation's Tasks that Could Technically Be Automated by an Existing Technology, vs Share of B.C. Employment in Potentially-Affected Occupations



Source: Chui et al. 2015, Lamb 2016, Statistics Canada, BCBC calculations.

5. PROFILES OF B.C.'S TOP OCCUPATIONS

Table 3 shows B.C.'s top 15 individual occupations by share of employment. Together, these occupations make up 26% of provincial employment. Most of B.C.'s top 15 occupations have a high probability of long-term automation. And about half of their tasks are automatable by an existing technology.

For example, the most common occupation in B.C. is "retail salesperson" with 91,000 jobs (albeit some of these jobs are part time). It is highly likely, from a technical perspective, that it will become possible to automate this occupation in the next 10-20 years. Today's technologies can already perform about half of the tasks found in this occupation. By contrast, B.C. has about 37,500 jobs in nursing. This occupation faces a low probability of automation over the next 10-20 years.[8] Less than one-third of tasks in nursing can be performed by an existing technology.

TABLE 3: **MANY OF B.C.'S TOP OCCUPATIONS WILL FACE AUTOMATION PRESSURES**

B.C. Employment by Individual Occupational Group

Occupation	Employment 2016	Median Income 2015 ($)	Probability of automation over the next 10-20 years *(Frey & Osbourne)*	Proportion of tasks technically automatable by an existing technology *(Chui et al.)*
Retail salespersons	90,825	16,880	92%	47%
Retail & wholesale trade managers	56,775	45,036	21%	28%
Food counter attendants, kitchen helpers & related support	53,185	9,958	92%	78%
Cashiers	38,830	11,094	97%	49%
Registered nurses & psychiatric nurses	37,530	67,466	1%	29%
Transport truck drivers	36,930	49,568	79%	69%
Food & beverage servers	35,445	12,170	94%	64%
General office support workers	34,190	31,893	96%	61%
Administrative officers	33,430	43,261	96%	54%
Cooks	31,825	19,448	83%	81%
Nurses' aides, orderlies & patient service associates	30,145	34,972	39%	39%
Elementary school & kindergarten teachers	30,035	58,943	0%	14%
Janitors, caretakers & building superintendents	29,770	27,478	66%	22%
Light duty cleaners	28,840	16,028	69%	18%
Financial auditors & accountants	27,290	55,445	94%	12%
TOTAL = 26% of B.C. Employment	**595,045**		**69%**	**46%**

Automation probabilities/proportions are classified as high ≥ 70% (red), moderate 30-69% (orange) and low <30% (green).

Source: Frey and Osbourne 2017, Chui et al. 2015, Lamb 2016, Statistics Canada, BCBC calculations.

[8] For example, it is not imminent that technologies will be able to perform nursing duties requiring "social intelligence" and "perception and manipulation" skills (see Table 1 earlier).

6. POLICY IMPLICATIONS

The central message for policy-makers and business decision-makers is that the digitalization of the economy is underway. Labour's role is changing in many production processes. There will be economic opportunities and adjustment costs. And they will require careful management.[9]

In aggregate, new technologies offer the potential to raise Canadian and B.C. living standards by increasing labour productivity (output produced per hour of labour input).[10] Governments should promote intense product market competition to spur productivity in the business sector. Survival is a powerful business motivator. "Creative destruction" should drive the reallocation of labour and capital to best use (across and within firms and industries), accelerate innovation and the diffusion of new technologies, and encourage firms to reap technology's full benefits by scaling up.[11] Governments will also need to provide regulatory frameworks and institutions suited to the emerging digital economy.

New job specializations will emerge that are complementary with technology. Automation will free up workers' time to pursue new occupations, new tasks within existing occupations, or to work less. The role of governments, educational institutions and firms is to incentivize, train and support people in acquiring new skills for the non-automatable production tasks of the future.

Adjustment costs are painful and can cause economic and social distress. Re-skilling, re-tasking and relocation will be essential as some current tasks are automated and new roles for labour emerge. Institutions play a crucial role in ensuring that citizens are not left behind and have an adequate and comparable quality of life in the face of technological change.

There will also be adjustment costs. The risk of job loss (or wage growth stagnation) due to automation could be disproportionately borne by workers in lower-income occupations. B.C. may see somewhat higher adjustment costs compared to Canada, given the composition of provincial employment. Automation could also exacerbate B.C.'s overall wage disadvantage compared to Canada, all else being equal.

Adjustment costs are painful and can cause economic and social distress. Re-skilling, re-tasking and relocation will be essential as some current tasks are automated and new roles for labour emerge. Public and private institutions play a crucial role in ensuring that citizens are not left behind and have an adequate and comparable quality of life in the face of technological change. Policy-makers will face pressure to review the design of taxation, labour market institutions (trade unions, productivity-linked wage bargaining, minimum wages, earned income tax credits, labour mobility impediments and pensions), and universal service provision (e.g. health, education and training).

Immigration policies should be carefully designed considering these technological developments. Future production processes will be more capital-intensive. Labour's role will increasingly be to provide advanced skills involving creative and social intelligence, and perception and manipulation. Production will not require large numbers of low- or mid-skill workers performing routine agricultural, industrial or clerical tasks. Those eras are long gone or soon will be.

Well-designed immigration programs can support productivity-driven economic growth and mitigate inequality in market wages by increasing the supply of high-skilled workers. Conversely, poorly-designed immigration programs that increase the supply of workers with automatable skill sets could exacerbate the costs of labour market adjustment and income inequality. This could also suppress wage growth for lower skill workers and in doing so, reduce firms' incentives to invest in new labour-saving technologies – leading to slower growth in capital intensity, labour productivity and living standards.

[9] The transition to the digital economy is unlikely to be smooth. Van Ark (2016) argues that advanced economies are still in an "installation phase," a lengthy period where new technologies will emerge and disrupt established practices and organizations. Schumpeter (1939, 1947) cautions that "creative destruction" during periods of transition could see potential economic growth slow before it accelerates. The slowing, in part, reflects the structural displacement, or technological unemployment, of certain types of labour (Keynes 1930).
[10] For a primer on digitalization and productivity, see D'Souza and Williams (2017).
[11] Williams 2018b discusses recent Bank of Canada evidence on the slowing pace of "creative destruction" in Canada. See Finlayson and Peacock (2017) on the importance of scaling up B.C. businesses.

7. METHODOLOGY IN DETAIL

Frey and Osbourne's (2017) seminal paper estimates that 47% of U.S. employment could, from a technical standpoint, be automated over the next 10-20 years. The authors begin by asking machine learning (ML) and mobile robotics (MR) experts to classify a sample of 70 U.S. occupations as "automatable" or "not automatable."[12] Second, they identify the associated engineering bottlenecks to automation. Third, they match the bottlenecks to O*NET descriptive variables contained in the 2010 U.S. Department of Labor database (see **Table 1** earlier). Fourth, they develop a way to extrapolate and assess the potential to automate all 903 occupations in the database based on the prevalence of engineering or technical bottlenecks. Finally, they aggregate their findings to match the 702 Standard Occupation Classification (SOC) codes for U.S. employment.

A McKinsey and Company study by Chui et al. (2015) takes a different approach. Rather than looking at whole occupations, the authors assess the tasks *within* occupations that could be automated by *current* technologies. For more than 750 occupations, they examined roughly 2,000 individual work activities. They assessed the requirements to perform the activities according to 18 capabilities (e.g. social, cognitive and physical functions) that potentially could be automated by technologies that already exist today. They highlight that while many jobs could soon see at least some tasks automated, only a small proportion of jobs could be fully automated in the near term.

The studies by Frey and Osbourne (2017) and Chui et al. (2015) yield numerical estimates of the potential for automation – albeit with different interpretations – for all six-digit U.S. SOC codes. Lamb (2016) maps these U.S. estimates to Canada's 500 four-digit NOCs. He then uses these numerical estimates to assess the scope for automation in the Canadian labour market, using occupational employment data from the 2011 National Household Survey. Our contribution in this paper is to update the analysis using 2016 Census data on employment by occupation and extend it to the B.C. labour market.

Automation will free up workers' time to pursue new occupations, new tasks within existing occupations, or to work less. The role of governments, educational institutions and firms is to incentivize, train and support people in acquiring new skills for the non-automatable production tasks of the future.

8. LIMITATIONS OF THE STUDY

There are several important limitations to our analysis. Fundamentally, automation will not only depend on overcoming engineering bottlenecks. First, the actual pace and extent of automation will depend on shifts in the demand and supply of labour and capital and their relative factor prices. All else being equal, if labour is relatively cheap and plentiful, the deployment of new labour saving technologies might be slow. Conversely, buoyant wage growth, surging retirements and the onset of labour shortages might accelerate the pace of automation.

Second, new technologies can increase productivity. Total labour demand could be higher if the income effect of higher GDP (or cheaper prices for goods and services) increases demand for labour by more than enough to offset job losses caused by labour substitution. New technologies can also spur demand for new job specialisations that have complementarities with technology. Our analysis excludes these effects.

Third, the actual pace and extent of automation in the economy will depend on regulatory frameworks and social acceptance of new technologies. For example, will passengers be permitted or even willing to fly in fully-automated commercial aircraft? Will governments, businesses and consumers embrace driverless vehicles? Policy-makers will also need to address the positive and negative externalities that arise as new technologies are implemented and the economy changes.

Fourth, it is only possible to estimate the technical potential for automation given what is known today about technology's likely development path. Breakthrough inventions might overcome engineering bottlenecks in

[12] Specifically, ML and MR experts were asked: "Can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by state of the art computer-controlled equipment?"

unforeseeable places and open new possibilities. The composition of the labour market will also change over time due to factors unrelated to automation. This will alter the estimated impacts of new technologies.

Fifth, a criticism of Frey and Osbourne's (2017) approach is that not all tasks within occupations are automatable. Using an alternative approach by Chui et al. (2015), it appears that only a few occupations face the near-term risk that their tasks could be fully automated. However, most workers could see at least *some* of their tasks automated by an existing technology. This is likely to free up time for workers to perform new tasks within occupations, pursue new occupations or work less.

9. CONCLUSION

The times they are a-changin'. About 42% of B.C. jobs are in occupations that have a high probability of being automated in the next 10-20 years, from a technical capabilities standpoint. This percentage is slightly higher than for Canada, indicating that B.C. could face more automation-related adjustment costs. Low-income occupations could bear a disproportionate share of the costs of re-tasking, re-skilling, relocation, job destruction or slower real wage growth due to automation. All else being equal, automation could also exacerbate B.C.'s income gap across occupations relative to Canada.

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There is also significant scope for *task* automation in the near-term. About 90% of B.C. jobs are in occupations where at least 10% of the tasks can be automated by a current technology, from a technical capabilities standpoint. About 35% of jobs are in occupations where at least 50% of tasks are automatable. And about 11% of jobs are in occupations where 80% or more of tasks are automatable.

Our study is a risk assessment. We have only considered the scope for automation from a technical perspective and based on the composition of provincial and Canadian employment. In practice, the pace and extent of automation will depend many factors not examined in this study. These include labour market dynamics, productivity, consumer prices and preferences, regulatory and social acceptance of new technologies, and unforeseeable engineering breakthroughs.

The central message for policy-makers and business decision-makers is that labour's role in the production process is changing. New technologies offer the potential to increase labour productivity, raise living standards and create new job specializations. However, there can also be significant, unevenly-distributed adjustment costs from job destruction and dislocation that cause economic and social distress. As Tugwell (1931) observed, well-designed institutions and policies will be crucial in smoothing these adjustments.

> *"In any new regime in which machines and power play a greater role than they do even today, men will not have become useless; but the nature of their tasks will have changed. It is man's destiny to perform those functions which machines can never do—the thinking and contriving ones. We shall be on the way to that destiny for a very long time, with various ups and downs during the transition. Our task is the double one of speeding the process and of taking precautions meanwhile against unnecessary personal and family loss and suffering. We are not excused from these duties in any case; and ways will somehow be found to meet them; they may be better or worse ways, but human revolt against intolerable conditions will insure some sort of action."*
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> Tugwell (1931, 227)[13]

[13] Rexford Tugwell was a professor of economics at several U.S. universities and an original member of U.S. President Franklin Roosevelt's New Deal "brains trust."

References

Berger, T. and C. Frey. 2016. "Structural Transformation in the OECD: Digitalisation, Deindustrialisation and the Future of Work." OECD Social, Employment and Migration Working Papers 193, Paris.

Bughin, J., Chui, M., Dewhurst, M. George, K., Manyika, J. and P. Willmott. 2017. "A Future That Works: Automation, Employment, and Productivity." McKinsey Global Institute, January.

Carney, M. 2018. "The Future of Work." Whitaker Lecture at the Central Bank of Ireland, Dublin, September 14.

Chui, M, Manyika, J. and M. Miremadi. 2015. "Four Fundamentals of Workplace Automation." McKinsey & Company.

D'Souza, C. and D. Williams. 2017. "The Digital Economy." *Bank of Canada Review*, Spring.

Finlayson, J. and K. Peacock. 2017. "From Good to Great: The Benefits of Scaling Up B.C. Business." Business Council of British Columbia.

Frey, C. and M. Osbourne. 2017. "The Future of Employment: How Susceptible Are Jobs to Computerisation?" *Technological Forecasting and Social Change* 114: 254-280.

Keynes, J. M. 1930. "Economic Possibilities for our Grandchildren." In *Essays in Persuasion*, (New York: Harcourt Brace, 1932), 358-373.

Lamb, C. 2016. "The Talented Mr. Robot: The Impact of Automation on Canada's Workforce." Brookfield Institute for Innovation and Entrepreneurship, June.

Nedelkoska, L. and G. Quintini. 2018. "Automation, Skills Use and Training." OECD Social, Employment and Migration Working Papers No. 202, Paris.

Oschinski, M. and R. Wyonch. 2017. "Future Shock? The Impact of Automation on Canada's Labour Market." C.D. Howe Institute, Human Capital Policy, Commentary No. 472, March.

St-Laurent, K. 2017. "What To Expect When You're Expecting [Disruption]: The Digital Economy and British Columbia." Business Council of British Columbia, *Policy Perspectives* 24 (4), November.

Schumpeter, J. A. 1939. Business Cycles: A Theoretical Historical and Statistical Analysis of the Capitalist Process. New York: McGraw-Hill Book Company.

—. 1947. "The Creative Response in Economic History." *Journal of Economic History* 7 (2): 149–159.

Tugwell, R. 1931. "The Theory of Occupational Adolescence." *Policy Science Quarterly* 46 (2): 171-227.

Van Ark, B. 2016. "The Productivity Paradox of the New Digital Economy." *International Productivity Monitor* 31: 3–18.

Wallace-Stephens, F. 2017. "How Many Jobs Will Robots Replace? And Why Does Everyone Disagree?" Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA), August.

Williams, D. 2018a. "The Automation Potential of the British Columbia Labour Market: Some Insights." Business Council of British Columbia, *Human Capital Law and Policy* 8 (3), October.

Williams, D. 2018b. "The Slowing Pace of 'Creative Destruction' in Canada." Business Council of British Columbia, B.C. Business Matters Blog, May.

Williams, D. 2018c. "Six Propositions about Digitalization and the Labour Market." Business Council of British Columbia, *Human Capital Law and Policy* 8 (2), June.