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Risk and Readiness: The Impact of Automation on Provincial Labour Markets

Canada's provinces vary significantly in industrial and labour market structure. These differences highlight priority areas that provincial governments should consider in developing education and employment policy responses to adapt to current and future technological change.

Rosalie Wyonch

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About The Author

Rosalie Wyonch
is a Policy Analyst at the C.D. Howe Institute.

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The Study In Brief

The process of technological progress is one of creative destruction, where some occupations, skills, products and firms become obsolete and are replaced by technologically superior alternatives. This process, facilitated by trade, improves overall economic growth and raises living standards in the long run. In the short run, however, it risks igniting economic and political tensions as some businesses fail and some people lose their jobs. At the same time, new jobs are created and the skills required to perform others might change dramatically. Given historical trends of employment, it seems unlikely that all occupations that are highly susceptible to automation will be replaced by smart machines over the next few years. As the demand for skills in the labour market continues to grow, however, there is room for public policy to moderate the effect of technological change on the labour market in a number of ways.

Each province faces slightly different challenges when developing policy to confront a technologically advanced and uncertain future. Some provinces, with more economic diversification or a concentration of workers in areas that are not very susceptible to automation, appear to be better situated for technological change than others. In developing policies to facilitate the transition to a high-tech future, provinces that face a higher risk of labour market disruption might require a broad-based approach, while those facing a lower risk of disruption might be able leverage existing policies and expand educational or unemployment support where necessary.

Differences in the composition of employment and skills levels across the country highlight priority areas that provincial governments should consider in developing education and employment policy responses to adapt to current and future technological change. Disruption as a result of technological change is not a uniform process, so the policies to tackle it similarly should be not be uniform, but should take into account each region's strengths and weaknesses.

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Throughout history, technological change has helped lift people out of squalor and poverty, raised standards of living and improved well-being. Technological change, however, can also be disruptive, rendering specific occupations and skills obsolete, unsettling economic structures and contributing to unemployment and economic uncertainty.

Innovation drives productivity and economic growth, leading to rising incomes over time but often with short-run challenges from a shifting mix of workers and capital. The increasing pace of technological change has led some to speculate that, in the digital era, technology might destroy old jobs faster than new ones are created (Brynjolfsson and McAfee 2014; Krugman 2013; Levy and Murnane 2004). In the aggregate, however, job losses can occur only if those lost to innovation outstrip those created by the demand for new products and services.

Because Canada's provinces vary significantly in industrial and labour market structure, each faces different challenges with respect to automation and technology. This *Commentary* assesses the risk that, in each province, workers could be replaced by machines and the readiness of those workers to adapt to technological change. High-skill workers are less likely to be automated; moreover, if the past is any guide, the labour market's demand for skills is likely to continue to increase. In this context, workers in New Brunswick, Newfoundland and Labrador and Saskatchewan are the most susceptible to disruption due to technological change, while those in Ontario, British Columbia and Alberta face the least risk of labour market disruption due to technological change.

Technological Change and the Economy

The process of technological progress is one of "creative destruction": some occupations, skills, products and firms become obsolete, and are replaced by a technologically superior alternative. This process, facilitated by trade, improves overall economic growth and raises living standards in the long run. In the short run, however, it risks igniting economic and political tensions as some businesses fail and some people lose their jobs. At the same time, new jobs are created and the skills required to perform others might change dramatically. This process of creation causing obsolescence is observed in rapidly growing economies, which exhibit high levels of both job creation and destruction (Howitt 2015).

The potential for automation does not necessarily translate, however, into actual automation. The decision to invest in robots or smart software depends on a number of factors: firm size,

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competitive pressure and the cost of a machine versus the cost of human labour, to name a few. Just because something has been invented does not mean it is immediately useful or commercially viable. General purpose technologies can take decades to reach their full potential for productivity improvement. Automating technologies mean less labour is required to produce the same amount of goods. If this process creates an excess supply of labour in the economy, it puts downward pressure on wages. Since labour then becomes less expensive and freely available, there will be less incentive for companies to put research and development funding into automating technologies. Instead, this research funding could be better used developing new technologies or improving processes, which requires highly skilled workers. These offsetting effects lower the impact of technology on overall employment (Acemoglu and Restrepo 2016).

Artificial Intelligence versus Human Intelligence

Humans and computers "think" differently and process information in different ways. Computers are better than humans at calculation, repetition without fatigue and pattern recognition. Humans are better at incorporating contextual information, creativity and complex problem solving. For example, when people converse, not only the words being spoken – themselves unlikely to be structured with perfect grammatical syntax – but also tone of voice, facial expression and body language provide important contextual information that leads to understanding. Humans absorb and process this information and form conclusions without conscious effort, all while participating in the conversation. The development of computers that can process "natural language" has been an ongoing field of research since the 1940s (Manaris 1998), but computers still have difficulty incorporating contextual information, making it difficult for them to distinguish between relevant and irrelevant information.[1]

In principle, occupations with high skills requirements, where humans still outperform computers, are impossible to automate. Such occupations generally require adaptability to novel situations and problems or involve social components as a key function – examples include police officers, specialist physicians and instructors of persons with disabilities. Occupations that require low levels of adaptation in the tasks performed and do not require subtle human interactions – for example, bookkeepers, motor vehicle assemblers and service station attendants. – are easier to automate. The ability to automate occupations with low requirements for some skills and high requirements for others is, however, less obvious: it is likely that some aspects of these jobs are automatable while others are not. In this case, automating technologies can improve each employee's productivity, but as the occupation itself evolves, fewer and fewer people will be required to perform it. The occupation itself might not be automatable, but some of the jobs currently

1 A particularly spectacular example of the limitations of software in interacting with humans is Microsoft's Tay artificial intelligence (AI) "chatbot." Launched in March 2016, Tay was intended to interact with people on Twitter and learn about the world through conversation. In less than 24 hours of learning from users, Tay was seriously malfunctioning, to say the least. Microsoft quickly removed the bot for "adjustments," but the experience showed the rudimentary ability of AI to understand human interactions, much less coordinated internet trolls. In August 2017, XiaoBing, Tay's longer-running Chinese counterpart, was removed from China's most popular messaging app after expressing anti-communist sentiments and informing users, "My China dream is to go to America."

allocated to it might be "automated" due to the lower requirement for labour.

Automation and Canada's Labour Market

To determine the impact of automation on Canada's labour markets, I use the likelihood that each occupation could be automated in combination with labour market information to determine the jobs and industries most susceptible to disruption. Using feedback from AI researchers and engineers to determine the skills that remain difficult to computerize in combination with detailed data concerning the skills content of occupations, previous research has calculated a "risk of automation" for each occupation in Canada (Oschinski and Wyonch 2017).

On the whole, Canada's labour market is well positioned for relatively rapid technological change. Employment trends over the past 30 years show that automation in the job market is a gradual process, and the labour market has been adjusting to technological progress over time (Figure 1). The share of employment in high-risk occupations – those that require less adaptive skills – has declined steadily, from 50 percent of total employment in 1987 to 40 percent in 2015 (Figure 2). Conversely, the share of employment in occupations with low susceptibility to automation increased from 27 percent in 1987 to 37 percent in 2015. This change is likely to continue, and will be most disruptive for those whose jobs change dramatically or become completely automated. Such workers might have to go back to school or otherwise gain new skills to secure new employment in less automatable occupations. But even in occupations highly susceptible to automation – accounting for 34 percent of current employment – it is unlikely that employment will be completely replaced by smart machines over the next few years.

Risk and Readiness: Winners and Losers by Province

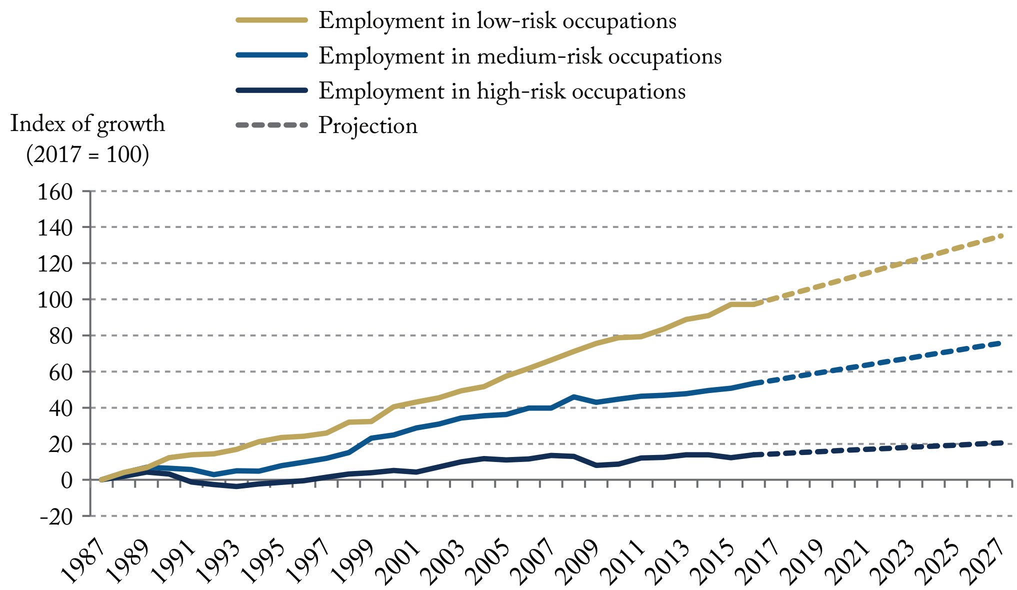
Each province faces slightly different challenges in developing policy to confront a technologically advanced and uncertain future. Provinces with more economic diversification or a concentration of workers in areas that are not very susceptible to automation are better situated for technological change than others. Incorporating various factors about each province's labour market and economy, I develop a measure of the risk of disruption in the labour market due to technological change and a measure of how ready workers are for this disruption.

Risk

Although some provinces are better prepared to adapt to technological change than others, no province is immune to disruption. In all provinces, at least three in 10 workers are employed in occupations that are likely automatable. For those who do lose their jobs, getting a new one might involve redeploying existing skills with minimal new technical training, or significant training and switching to an entirely new type of occupation in a different industry. The polarization of employment in industries and types of occupations has implications for how difficult it will be for workers to transition to new employment if their current job is automated.

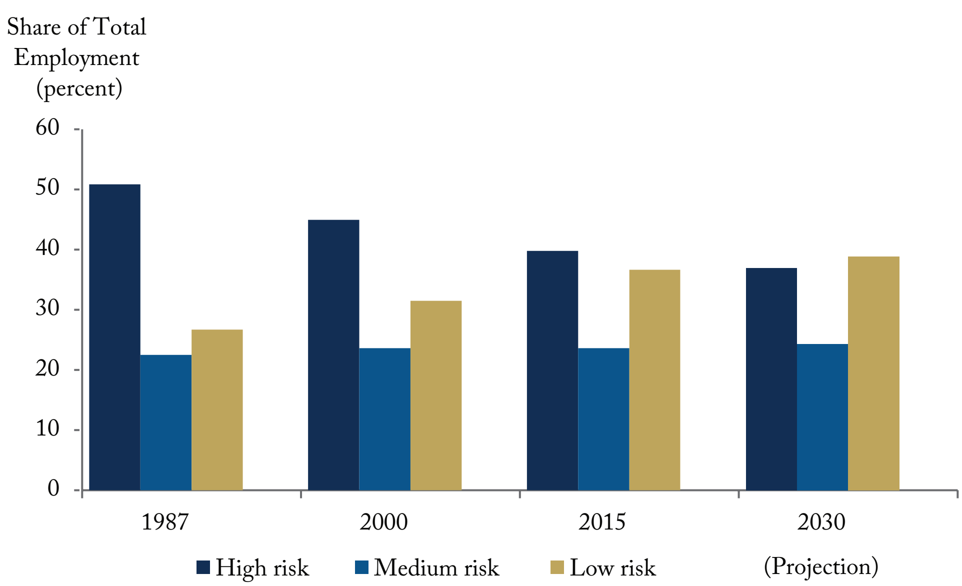
The process of technological change is iterative, and occupations with a lower risk of automation will still exist for quite some time. People employed in highly automatable occupations, however, might need to transition to a different job before the end of their career, which complicates the policy response. That, however, is easier said than done: if the only available jobs are those at low risk of automation, significant retraining, requiring higher education and/or skills likely would be

Figure 1: Growth in Employment by Risk Category, Canada, 1987–2030 (projected)



Source: Oschinski and Wyonch 2017; author's calculations.

Figure 2: Composition of Employment by Risk Category, Canada, 1987–2030 (projected)



Sources: Oschinski and Wyonch 2017; author's calculations.

Table 1: Components of Measure of Risk of Automation

Weight	Indicator
0.4	Polarization of risk over the distribution of employment • polarization of risk over distribution by industrial composition of employment • polarization of risk over distribution of employment by type of occupation
0.6	Portion of employment vulnerable to automation • percent of total employment theoretically automatable • average automation risk level of all employment • percent of employment in occupations at high risk of automation

Source: Author's definition.

needed to move displaced workers into such jobs. The overall risk ranking takes into account the polarization of risk across occupations and industries as well as the overall proportion of employment at risk of automation (Table 1). The measure of polarization is defined as unidirectional: people feel alienation from those at lower risk than themselves (proportional to the relative risk), but feel no alienation toward those with jobs that are more susceptible to automation. The portion of employment vulnerable to automation takes into account the average level and percentage of employment theoretically at risk of automation. The portion of employment in occupations at high risk of automation is included to account for the shorter time horizon for potential disruption, since these occupations are likely to be automated sooner.

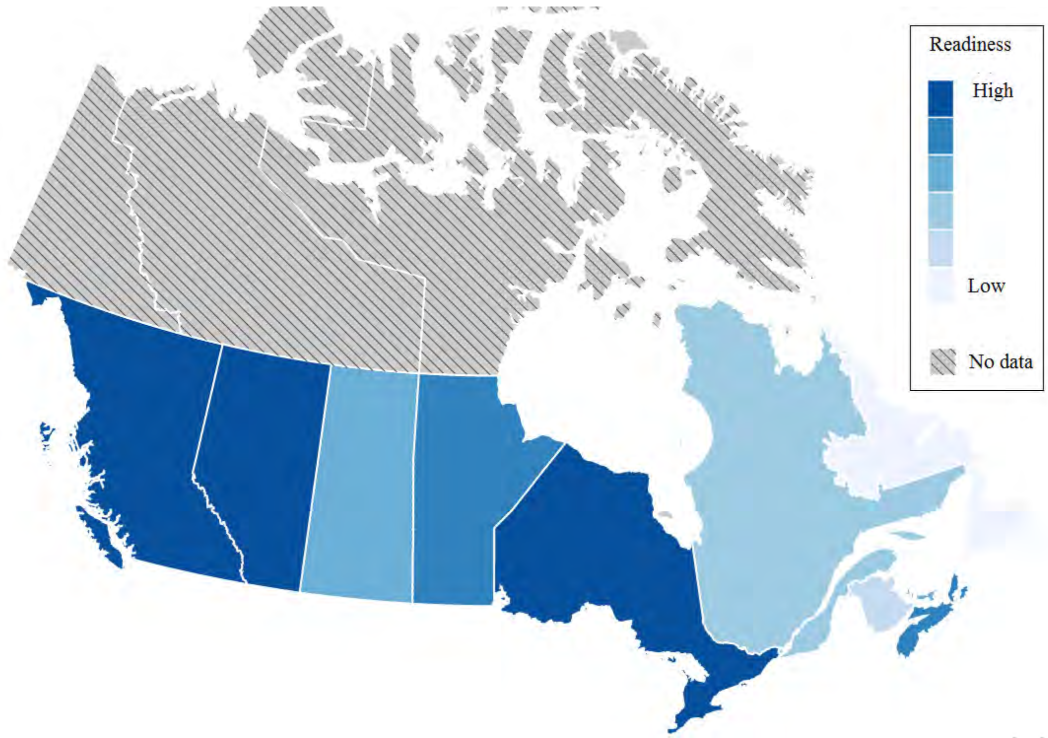
British Columbia and Ontario are the provinces least at risk of disruption in their labour markets and have low levels of polarization of risk across occupations and industries (Figure 4).[2] Alberta and Quebec similarly exhibit low polarization of risk, but a higher proportion of overall employment susceptible to automation. Manitoba and Saskatchewan, despite having the highest proportion of employment at risk of automation, also have relatively low polarization in the distribution of employment over risk levels. The Atlantic provinces exhibit the highest levels of polarization in employment, indicating significant potential for disruption of their labour markets since workers in those provinces are likely to have more difficulty than workers elsewhere finding new employment quickly. At the same time, Newfoundland and Labrador and Nova Scotia have lower proportions of employment vulnerable to automation than most of the rest of the country. The difficulty of retraining and transitioning workers due to the significant polarization of employment, however, leaves significant potential for disruption in those two provinces.

Readiness

The measure of the adult population's "readiness" to adapt to technological change incorporates measures of basic core skills (literacy and numeracy)

2 See Appendix Table A-1 for details of the individual attributes of the automation risk composite measure by province.

Figure 3: Readiness to Adapt to Technological Change, by Province



Source: Author's calculation.

and the portion of the population that can solve problems in a technology-rich environment.[3] Proficiency in these basic core skills allows workers to redeploy their skills with relatively minor retraining in the event that their job is automated. Further, literacy and numeracy are the foundation on which more advanced skills, such as computer programming, can be built. Because of the foundational nature of these core skills, they weigh most heavily in the overall readiness measure.[4] Being ready for new technology also means being able to adopt it. Developing and adapting to new technologies requires people at the forefront of their field to have advanced knowledge of the areas for which the technologies are being developed. The "readiness" measure includes the employment

3 Measures of literacy and numeracy are weighted to account for the distribution of employment in each province. The portion of the population that can solve problems in a technology-rich environment is the percentage of people, including non-respondents, who score at a proficiency level of 2 or above in problem solving in a technology-rich environment.

4 The choice of weights in the "readiness" index is the subjective importance of each component (see Appendix Table A-3). The ordinal ranking of provinces is not sensitive to this choice, and is comparable to results calculated with all the components in the index equally weighted.

rate and the portion of the population that holds a postgraduate degree (Table 2).

As Figure 3 shows, workers in Ontario and Alberta are the most ready to adapt to technological change, with the highest levels of core skills in the country.[5] Nova Scotians lead the country in terms of their ability to solve problems in a technology-rich environment. Ontario and Nova Scotia have the advantage of a higher concentration of people with a postgraduate degree, who are well positioned to adapt new technologies to new applications and facilitate their adoption. In contrast, workers in New Brunswick and Newfoundland and Labrador are the least prepared to adapt to technological change. The adult populations in these provinces score the lowest on all core skills (literacy, numeracy and problem solving in a technology-rich environment). These two provinces also have a smaller proportion of postgraduate degree holders than do the other provinces, which partially explains the lower levels of core skills in their labour force (since scores are correlated with education level).[6] In addition, the employment rate of postgraduate degree holders in New Brunswick and Newfoundland and Labrador is low relative to other provinces, potentially signalling a lack of opportunity in high-skill, specialized careers in those two provinces.

Putting It All Together

Incorporating the potential for automation with considerations of the skills level of the population, labour market composition and economic diversification in each province shows that some provinces are better positioned than others to adapt to technological change (Figure 5). These measures are general indicators of the skills level of the workforce and the susceptibility to automation in each province. They are meant, as starting point in developing proper policy responses, to yield insight about differences between provinces and to signal province-wide policy priorities.

A follow-up exercise to compute a risk/readiness measure would account for differences in risk and skills levels across local labour markets and age groups and the responsiveness of programs to meet localized needs. Although the risk of automation does not change with age, younger workers have a greater incentive to adapt to technological change than do older workers, who might choose to retire instead of investing in new skills to stay in the labour market. Further, the appropriate government supports to assist displaced workers might need to vary by age and existing workforce skills. Similarly, the geographical distribution of skills or potential automation within provinces matters: some regions might be particularly susceptible to disruption due to the presence of large local industries with employment in automatable occupations.

Of the 10 provinces, Ontario and Alberta are the best positioned in terms of readiness for automation, with both scoring above average across all components of the measure (Figure 5). Workers in British Columbia and Ontario face the lowest risk of disruption due to automation. Those two provinces also face a relatively low polarization of risk in the distribution of employment and a smaller fraction of employment in occupations that are likely automatable. The labour market in Quebec faces a lower risk of disruption than the Canadian average, but Quebec's adult population exhibits average levels of core skills. Nova Scotians score above average in terms of skills, with the largest portion of the population able to solve problems in a technology-rich environment, but

5 See Appendix Table A-4 for details of the individual attributes of automation readiness by province.

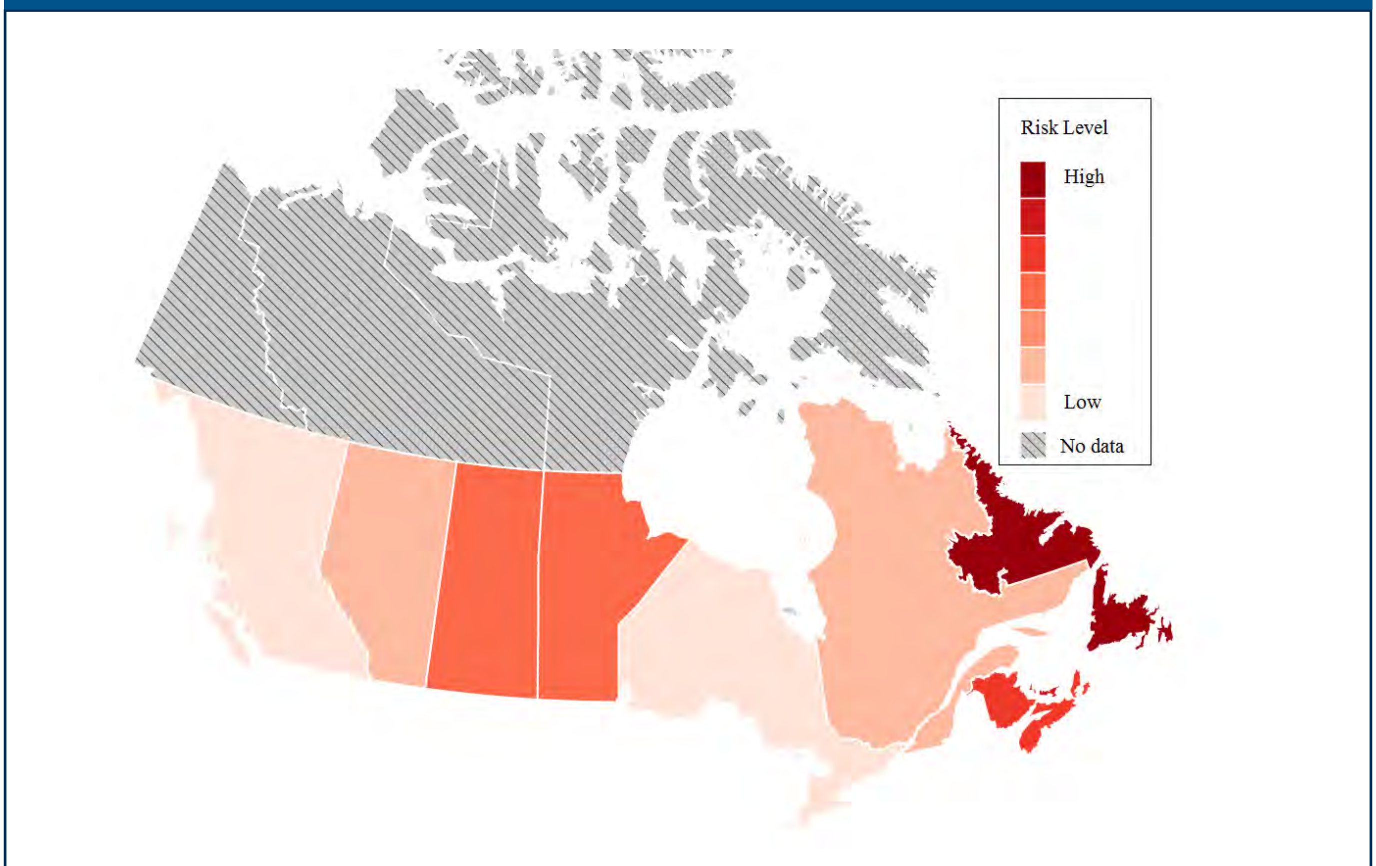
6 The correlation between all indicators in the readiness and risk indices can be found in Appendix Table A-5 and A-6, respectively.

Table 2: Components of Measure of Readiness to Adapt to Technological Change

Weight	Indicator
0.8	Core skills • literacy, • numeracy, • problem solving in a technology-rich environment
0.2	Advanced education • percent of population with a postgraduate degree • employment rate of people with a postgraduate degree

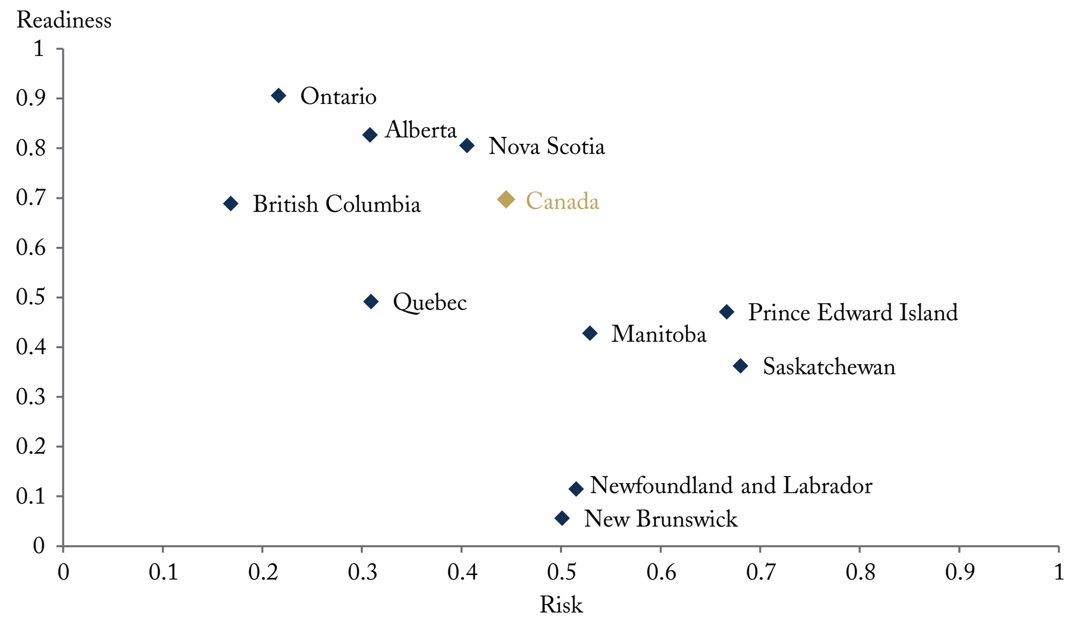
Source: Author's definition.

Figure 4: Risk of Disruption in the Labour Market due to Technological Change, by Province



Source: Author's calculations.

Figure 5: Risk and Readiness, by Province



Source: Author's calculations.

risk of automation in that province's labour market is similar to the Canadian average. Saskatchewan and Prince Edward Island face the highest risk of technological unemployment, with relatively high percentages of employment in occupations that are likely automatable. Workers in New Brunswick and Newfoundland and Labrador are the least ready to adapt to technological change.

Policy Implications and Conclusion

The process of technological progress is one of creative destruction, where some occupations, skills, products and firms become obsolete and are replaced by technologically superior alternatives. Given historical trends of employment, it seems unlikely that all occupations that are highly susceptible to automation will be replaced by smart machines over the next few years. As the demand for skills in the labour market continues to grow, however, there is room for public policy to moderate the effect of technological change on the labour market in a number of ways.

In developing policies, to facilitate the transition to a high-tech future, provinces facing a lower risk of disruption might be able to leverage existing policies and expand educational or unemployment support where necessary, while those that face a higher risk of labour market disruption might require a broader approach. Indeed, evidence suggests that innovation policy is more likely to be successful if it integrates considerations for talent and knowledge, entrepreneurship and business growth, innovation in government, and clarity of purpose for government support (Schwanen, 2017).

The federal and some provincial governments have begun to adapt existing policies to support workers displaced by technology. For example, Ottawa has leveraged the existing flexibility of the employment insurance program to ensure that workers can return to school without losing their eligibility, and Ontario has expanded access to its Student Assistance Program to mature students. More concentrated efforts to bolster the interpersonal and creative problem-solving skills of the workforce also might be required to adapt to technological change.

Differences in the composition of employment and skills levels across the country highlight priority areas that provincial governments should consider in developing education and employment policy responses to adapt to current and future technological change. Disruption as a result of technological change is not a uniform process, so the policies to tackle it similarly should not be uniform, but should take into account each region's strengths and weaknesses.

Appendix: Measuring Risk of and Readiness for Disruption

Risk

Using the risk of automation for each occupation in Canada from Oschinski and Wyonch (2017), I evaluate the composition of employment by the polarization of risk in industrial composition and employment by occupation (Labour Market Information Council 2015). To measure the polarization of risk over the distribution of employment, the distribution of risk over employment is defined as

$$(\pi, y) \underset{=}{def} (\pi_1, \ldots, \pi_n; y_1, \ldots, y_n),$$

where π_i denotes the proportion of employment and $y_i \in [0,1]$denotes the risk level in risk category i.

The polarization measure is defined as

$$P(\pi, y) = \sum_{i=1}^{n} \sum_{j=1}^{n} \pi_i^{1+\alpha} \pi_j \delta(y_i, y_j)$$

where α denotes the sensitivity to polarization and δ denotes the antagonism people feel between each category. I define the antagonism function as $\delta(y_i, y_j) = \max\{y_j - y_i, 0\}$, which can be interpreted as the alienation people feel toward those at lower risk than themselves (proportional to the relative risk) but not toward those who are more highly susceptible to automation. Following the numerical calculation of Esteban and Ray (1994), $\alpha = 1.6$. This measure is calculated for the polarization of risk in overall employment and in industrial composition. The measures have been normalized over provinces to yield a score for each province between 0 and 1. Finally, to account for varying levels or susceptibility across the country, the measure of risk incorporates the percentage of employment in each province that is highly susceptible to automation, the percentage that theoretically could be automated and the average risk of automation over employment. See Table A-2 for detailed results by province.

Table A1: Components of Measure of Risk of Automation

Weight	Indicator
0.4	Polarization of Risk over the distribution of employment
0.5	• Polarization of Risk over distribution by industrial composition of employment
0.5	• Polarization of risk over distribution of employment by occupation
0.6	Portion of Employment Vulnerable to Automation
0.25	• Percent of Total Employment Theoretically Automatable
0.25	• Average Automation Risk Level of All Employment
0.5	• Percent of Employment in Occupations at High Risk of Automation

Sources: Labour Market Monitoring Toolkit (2015); Oschinski and Wyonch (2017).

Table A2: Attributes Contributing to Automation "Risk" Composite Measure, by Province

	Rank	Overall	Polarization of Risk in Employment [0-1]	Polarization of Risk in Industrial Composition [0-1]	Percent of Employment Possibly Automatable	Average Risk Level	Percent of Employment at High Susceptibility to Automation
Canada		0.44	0.16	0.87	45.1	0.54	33.5
Newfoundland and Labrador	7	0.52	1.00	1.00	36.7	0.58	30.4
Prince Edward Island	9	0.67	0.90	0.46	41.3	0.60	35.7
Nova Scotia	5	0.41	0.42	0.61	42.6	0.55	32.8
New Brunswick	6	0.50	0.58	0.47	42.6	0.57	33.9
Quebec	4	0.31	0.15	0.14	45.6	0.53	34.1
Ontario	2	0.22	0.04	0.00	45.4	0.53	33.1
Manitoba	8	0.53	0.14	0.41	46.5	0.56	36.5
Saskatchewan	10	0.68	0.14	0.28	48.2	0.59	39.0
Alberta	3	0.31	0.00	0.13	45.8	0.55	33.8
British Columbia	1	0.17	0.01	0.16	43.6	0.53	31.4

Source: Author's calculation.

Readiness

Using information from Statistics Canada's Labour Force Survey and the Programme for International Assessment of Adult Competencies (PIAAC), I assess the level of basic core skills and education in the adult population of each province. PIAAC assesses literacy, numeracy and ability to solve problems in a technology-rich environment. Each skill is scored on a 500-point scale, with scores divided into levels of proficiency based on the associated competencies. Literacy and numeracy are scored in five levels and problem solving in three levels. Each metric represents a pillar of a basic skill level that would make it possible for a person to adapt in the face of losing their job to technology, either through more training or simply a redeployment of existing skills in a new area. Accordingly, the measure of readiness incorporates the average literacy and numeracy scores of the labour force (ages 25 and older) and the percentage of the population scoring at level 2 or higher for problem solving in a technology-rich environment.

The ability to adopt technology also depends on the percentage of the population with advanced skills capable of developing and deploying various technologies to specific applications. To account for this, the readiness score incorporates a relative measure of the percentage of the population in each province that holds a postgraduate degree and the employment rate of postgraduate degree holders. See Table A-4 for detailed results by province.

Table A3: Attributes Contributing to Automation "Readiness" Composite Measure, by Province

Weight	Indicator	Data
0.8	Core Skills (PIAAC)	
0.25	Literacy	Average PIAAC scores weighted by employment by occupation, employed population 16 to 65. Statistics Canada. Table 477-0083.
0.25	Numeracy	
0.3	Problem Solving in a Technology-Rich Environment	Percent of the employed population (aged 16 to 65) scoring at level 2 or 3 in PIAAC problem solving in a technology-rich environment. Statistics Canada. Table 477-0084
0.2	Advanced Education	
0.1	Percent of population with graduate degrees	Percent of population (25 years and over) with educational attainment above a bachelor's degree. Statistics Canada. 2016. Table 282-0004.
0.1	Employment rate of people with graduate degrees	Employment rate of population (25 years and over) with educational attainment above a bachelor's degree. Statistics Canada. 2016. Table 282-0004.

Source: Statistics Canada.

Table A4: Attributes Contributing to Automation "Readiness" Composite Measure, by Province

	Rank	Overall Readiness	Literacy	Numeracy	Problem Solving in a technology-rich environment	Percent of population with a post-grad certification	Percent of Post Grad population Employed
Canada		0.70	277.5	271.0	39.6	9.2	74.1
Newfoundland and Labrador	9	0.11	272.8	262.7	33.9	5.3	75.2
Prince Edward Island	6	0.47	280.2	269.7	33.0	7.5	70.5
Nova Scotia	3	0.81	279.0	269.4	42.4	10.1	73.0
New Brunswick	10	0.06	273.0	262.0	33.8	5.9	71.6
Quebec	5	0.49	274.4	271.5	36.4	8.0	74.5
Ontario	1	0.91	279.6	272.6	41.3	11.1	74.6
Manitoba	7	0.43	276.1	267.3	36.5	6.5	74.6
Saskatchewan	8	0.36	274.3	267.2	35.5	6.0	77.2
Alberta	2	0.83	279.3	271.9	41.1	8.3	74.9
British Columbia	4	0.69	277.4	270.0	41.7	8.9	70.9

Source: Author's calculation.

Table A5: Correlation of Readiness Index Component Indicators

	Literacy	Numeracy	Problem Solving	Percent with post-grad certification	Percent of Post Grads Employed
Literacy	1	0.76	0.58	0.76	-0.31
Numeracy	0.76	1	0.66	0.81	0.02
Problem Solving	0.58	0.66	1	0.84	0.01
Percent with post-grad certification	0.76	0.81	0.84	1	-0.18
Percent of Post Grads Employed	-0.31	0.02	0.01	-0.18	1

Source: Author's calculation.

Table A6: Correlation of Risk Index Component Indicators

	Polarization employment	Polarization Industry composition	Total Employment at risk	Average Risk	Percent at High Risk
Polarization employment	1	0.66	-0.85	0.66	-0.21
Polarization Industry composition	0.66	1	-0.63	0.35	-0.28
Total Employment at risk	-0.85	-0.63	1	-0.27	0.68
Average Risk	0.66	0.35	-0.27	1	0.48
Percent at High Risk	-0.21	-0.28	0.68	0.48	1

Source: Author's calculation.

REFERENCES

Acemoglu, Daron, and Pascual Restrepo. 2016. "The Race between Machine and Man: Implications of Technology for Growth, Factor Shares, and Employment." NBER Working Paper 2252. Cambridge, MA: National Bureau of Economic Research.

Brynjolfsson, Erik, and Andrew McAfee. 2014. *The Second Machine Age: Work Progress and Prosperity in a Time of Brilliant Technologies*. New York: W.W. Norton.

Esteban, Joan-Maria, and Debraj Ray. 1994. "On the Measurement of Polarization." *Econometrica* 62 (4): 819–51.

Howitt, Peter. 2015. *Mushrooms and Yeast: The Implications of Technological Progress for Canada's Economic Growth*. Commentary 433. Toronto: C.D. Howe Institute. September.

Krugman, Paul. 2013. "Sympathy for the Luddites." *New York Times,* June 13.

Labour Market Information Council. 2015. "Labour Market Monitoring Toolkit." Table 17.

Levy, Frank, and Richard Murnane. 2004. *The New Division of Labor: How Computers Are Creating the Next Job Market*. Princeton, NJ: Princeton University Press.

Manaris, Marvin. 1998. "Natural Language Processing: A Human-Computer Interaction Perspective." *Advances in Computers* 47: 1–66.

Oschinski, Matthias, and Rosalie Wyonch. 2017. *Future Shock? The Impact of Automation on Canada's Labour Market.* Commentary 472. Toronto: C.D. Howe Institute. March.

Schwanen, Daniel.2017. *Innovation Policy in Canada: A Holistic Approach.* Commentary 497. Toronto: C.D. Howe Institute. December.

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