

The Employment-Impact of Automation in Canada

by

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Abstract

Standard neoclassical models of labour demand predict that automation does not produce long-term increases in unemployment. Supporting evidence in Canada between 1970 and 2008 is explained by the reallocation of labour from industries with high levels of automation such as Manufacturing to industries with low levels of automation such as Retail and Wholesale Trade, and Business Services. Recent evidence indicates however that on-going technological advances are now driving labour automation in many industries, and will likely expand to others in the near future. As automation technologies grow more sophisticated and decline in cost, Canada faces the prospect of historically high levels of structural unemployment due to declining labour demand. The study utilizes previous work on occupation-level automation probabilities to estimate the impact of automation on Canadian employment over the next two decades. Findings suggest that up to 50% of Canadian jobs will be at high risk for automation over this time frame. Suggested policies for minimizing unemployment include a nationally coordinated education and skills-training framework, and greater publically-funded assistance for the creation and development of small- and medium-sized enterprises. Beyond the next two decades the study suggests that policies will need to shift in focus from employment to redistribution.

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Executive Summary

According to neo-classical labour models, technological advances in production processes can cause temporary reductions in labour demand, but that increased productivity leads to economic growth and offsetting increases in labour demand. Three empirical implications emerge from the theory: first, short-term labour demand can run both with and against long-term labour demand trends; second, the spread of labour substituting technologies in an industry will cause the share of total employment in that industry to fall; and third, declining labour demand driven by labour substituting technologies in one industry will be offset by increasing labour demand in other industries. Therefore, persistent increases in unemployment due to spreading automation technologies should not occur.

Between 1970 and 2008 industry-level capital-labour ratios increased substantially in almost every Canadian industry, indicating the increasing use of technology in production processes. Over the same period, shares of total employment declined sharply in Manufacturing, and increased significantly in Business Services, and Wholesale and Retail Trade. Although unemployment fluctuated over this period, no clear trend of increasing unemployment emerges. These facts appear to confirm the implications of neo-classical theory. There are other signs, however, that new technologies have had a negative impact on labour demand since 1970. Average annual hours worked in Canada declined 10.5%, and involuntary part-time labour as a percentage of total employment increased significantly.

There is evidence that advances in new automation technologies could lead to further weakening of labour demand. Research into falling shares of employment in low-skill office-based occupations over the last two decades links the phenomenon to the spread of increasingly sophisticated information and communications technologies. Shares of employment in low-skill service and labour occupations increased over this period; however there are numerous signals that automation technologies are rapidly making many of these occupations obsolete as well. High-skill occupations do not appear to be susceptible to automation in the near term, but technologies on the horizon raise questions about how long this will be the case.

Although automation technologies create a variety of benefits linked to increasing productivity, unemployment has significant costs: declining income and consumption, reduced physical and mental health, negative impacts on family relationships and the educational outcomes of children, and decreased likelihood of maintaining future employment. Thus, high levels of automation-driven unemployment entail significant economic and social costs.

The policy problem that emerges in the Canadian context is: The susceptibility of an increasing number of occupations to automation may lead to historically high levels of structural unemployment in coming decades. To address this problem, policy-makers must have an understanding of the potential magnitude of the issue, leading to the research question: how many Canadian jobs could be lost due to automation in coming decades?

Recent research has attempted to identify how susceptible current occupations are to automation over the next two decades. Findings indicate that 47% of current occupations are at high risk. To determine the potential number of Canadian jobs at high risk within these occupations, I apply occupation-level automation probabilities from previous research to occupation-level employment data for 2013 and projections for 2022. The results indicate that 43% to 50% of employment in current occupations is at high risk for automation over this period. Industry groupings with the highest proportion of jobs at high risk for automation (>50%) are Processing, Manufacturing, and Utilities; Business, Finance, and Administration; Sales and Service; and Trades, Transport, Equipment Operators, and Related. Industry groupings with the lowest proportion of jobs at high risk (<10%) are Art, Culture, Recreation, and Sports; Natural, Applied Science, and Related; Social Science, Education, Government, and Religion; and Management. The actual number of jobs lost is likely to be lower than these estimates due to factors affecting firms' propensity to adopt new technologies that are not taken into account here, such as firm size and consumer preferences.

I evaluate three policy options to mitigate rising automation-driven unemployment using a set of criteria: equity, effectiveness, cost, administrative complexity, and stakeholder acceptability. The first policy option is the creation of a national skills-

training framework administered by a federally-led intergovernmental council of ministers. The council would set broad objectives, funding priorities, and performance targets to ensure that Canadian workers are able transition to high-skill occupations that are less-susceptible to automation in the near-term. The second policy option is to use a variety of policy instruments to incentivize firms to hire low-skill unemployed workers and provide training for high-skill occupations. The third policy option is to consolidate and increase support for the creation and development of viable small-and-medium size enterprises (SME) through the Business Development Bank of Canada. Because SMEs have been found to be slower to adopt new technologies, the aim of this policy is to stimulate labour demand in the private sector. The policy response that is found to be most favourable is a combination of options one and three, as it addresses both labour supply and demand aspects of the policy problem. This provides flexibility to policymakers as the nature of the problem changes over time from a lack of demand for low- and medium-skilled labour to a lack of aggregate labour demand across the entire skill-distribution.

In the long-term, advances in automation technologies and falling costs could produce permanently low levels of labour demand compared to supply at all skill-levels. In this context, policies will need to switch from a focus on mitigating unemployment to maintaining a minimum standard of living for Canadians. One potential option is income redistribution through a universal basic income, though such proposals face many fiscal and normative challenges.

1. Introduction

Predictions that automation will lead to increased unemployment have been made since at least the nineteenth century, as have counterarguments by economists predicting increasing employment opportunities instead. Employment trends in the 20th century appear to have vindicated the counterarguments. The introduction of automation technologies into agriculture in the first half of the century and later into manufacturing did not produce mass unemployment, but rather a change in the type and variety of work people engage in.

Despite this evidence, concern about the employment-impact of new automation technologies in the 21st century is rising. This new round of debate is driven by research into declining shares of total employment in low-skill office-based occupations in most developed countries over the last two decades. Many researchers attribute this pattern to the development of information and communications technologies that have made these occupations increasingly obsolete (Autor and Dorn, 2013; Goos and Manning, 2007). More recently, signals have begun to appear that advances in software and robotics could soon erode employment in low-skill service and manual labour occupations as well (see Chapter 4). The increasing scope and rapidity of these developments has led many researchers to argue that automation in the 21st century differs from previous episodes, and that significant increases in unemployment are possible if policy action is not taken.¹ Unemployment has a variety of economic and social costs, such as decreased income and consumption, adverse physical and mental health effects, and decreased future earnings for children of the unemployed. If current and developing automation technologies lead to significant increases in unemployment, these costs could become very large.

¹ For popular treatments of these arguments see Ford (2009) and Brynjolfsson and McAfee (2014).

This study examines evidence for the claim that current and developing automation technologies could lead to declining labour demand and significantly increased unemployment in Canada over the next two decades. Occupation-level automation probabilities developed by Frey and Osborne (2013) are used to estimate an answer to the following research question: How many Canadian jobs are at high risk for automation over the next two decades? The results of these estimates are used to inform the selection and evaluation of policy options at the federal level.

The study is organized into the following chapters: Chapter 2 describes a standard neo-classical labour model and draws out empirical implications of the theory. Chapter 3 examines changes in industry-level capital-labour ratios, changes in the industry-level shares of total employment, and changes in the national unemployment rate between 1970 and 2008 in Canada to test the implications of the neo-classical model. Chapter 4 examines contemporary evidence and signals that indicate increasing automation capabilities and their spread into non-manufacturing sectors of the economy. Chapter 5 provides an overview of the benefits and costs of automation. Chapter 6 gives a description of the policy problem and stakeholders. Chapter 7 describes the labour model underlying techniques used to answer the research question, and examines the model's ability to account for evidence and signals for weakening labour demand. Chapter 8 presents results and analysis of estimates relating to the research question. Chapter 9 discusses the policy objective, criteria, measures. Chapter 10 contains a description and evaluation of the policy options, and recommendations. Chapter 11 discusses long-term considerations relating to the policy problem. And finally, Chapter 12 offers concluding remarks.

2. The Neo-Classical Theory of Labour Demand

Neo-classical theories of labour demand start from the question: How can firms determine the optimal amount of labour to utilize in production processes?² The answer is captured in a model of decision-making called the Marginal Productivity Theory of Labour Demand (MPLD). It rests on four simplifying assumptions. (1) The goal of each firm is to maximize profits; (2) Firms work with only two inputs to production: physical capital and labour;³ (3) Firms operate in perfectly competitive product and labour markets;⁴ and (4) wages are the only cost of labour. In addition, a central principle of the MPLD is that firms face different choices and constraints in the short-run than they do in the long-run. In this chapter I discuss how the MPLD models these choices and constraints, how technological change impacts labour demand, and what empirical implications follow from the MPLD.

2.1 Labour Demand in the Short-Run

A firm utilizes a mix of physical capital and labour to produce output. The ratio of physical capital and labour inputs can change; however it takes more time to alter the stock of physical capital than to alter the level of labour in production processes. As such, the short-run is defined as the period in which the stock of physical capital is fixed and only labour can be altered.

In the short-run a firm must identify the optimal amount of labour to utilize given their current stock of physical capital. The solution relies on the law of diminishing returns (LDR). It states that when one input is held constant (e.g. physical capital), each additional unit of the other factor (e.g. labour) increases total output at a decreasing rate.

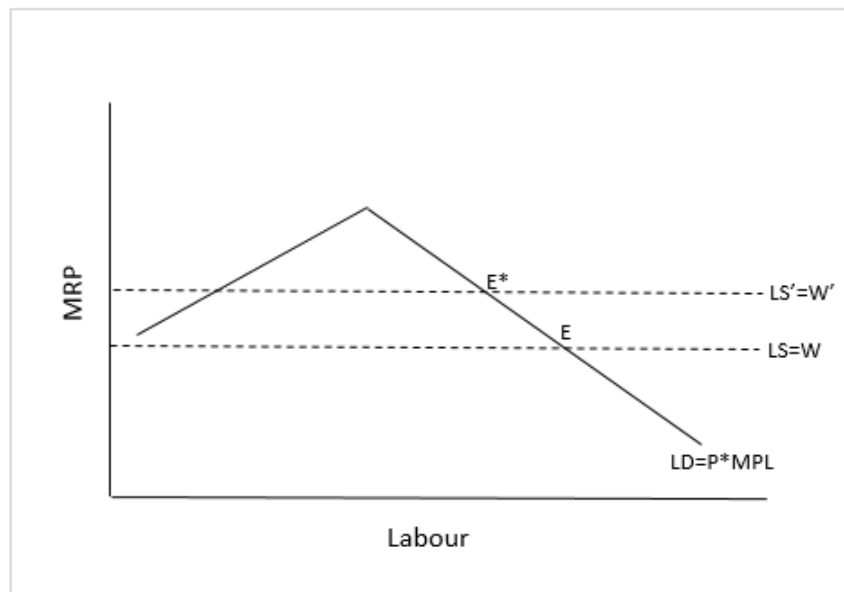
² Information in this chapter is drawn from Kaufman (1991).

³ Physical capital consists of assets such as machinery and equipment, buildings, and inventory.

⁴ This assumption implies that firms take product prices and wages as given by the market.

The LDR implies that for a fixed stock of physical capital, firms see their marginal revenue decrease with each additional unit of labour. Profit maximization requires firms to equate marginal revenue with marginal cost. The increase in revenue each unit of labour brings in is called its marginal revenue product (MRP_L); it is the increase in output that a marginal input produces (i.e. marginal labour product) multiplied by the output price (i.e. marginal price). The cost of labour is the wage W that is paid to workers. Thus, in the short term, firms employ labour up to the point where $MRP_L = W$ (Figure 1, point E). Beyond this point, revenue generated by an additional unit of labour is less than the cost of paying that worker, causing marginal losses.

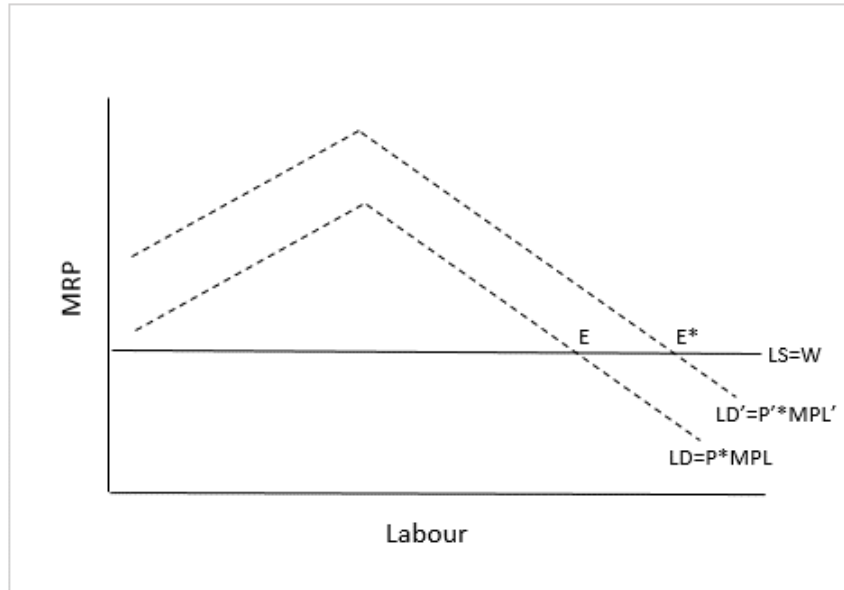
Figure 1. Firm-level Optimal Labour in the Short-Run Before and After Increase in Wage



The MPLD also describes what happens to a firm's labour demand when conditions change. If wages increase a firm must reduce its workforce to the new point where $MRP_L = W'_L$ holds (Figure 1, point E^*). A change in wages causes movement along the short-run labour demand curve. When demand for a firm's product changes however, the short-run labour demand curve itself shifts (Figure 2). In a competitive market, greater demand for a firm's product will increase the price of the good. The result is higher revenue per unit sold, and so a higher MRP_L for each unit of labour. With

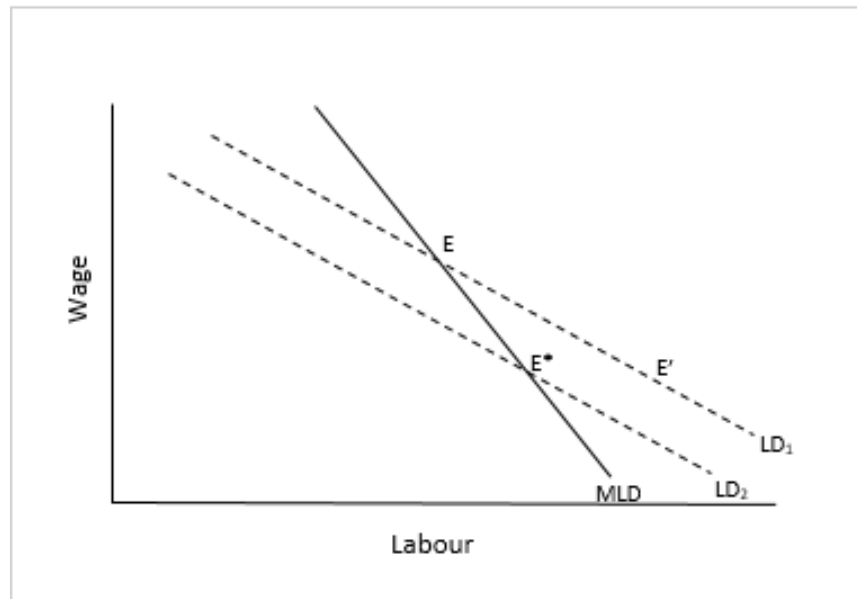
wages held constant, the increased MRP_L allows the firm to hire more workers up to the new point where $MRP_L' = W_L$ (Figure 2, point E^*)

Figure 2. Firm-level Optimal Labour After Increase in Product Demand



Short-run demand curves for labour, each representing a single firm, are used to construct the market-level demand curve for labour. Suppose the wage drops. All firms can then hire more labour for the given price of output, and there is a move along their demand curve for labour from LD_1 from E to E' in Figure 3. However with higher employment, all firms are now producing more output. The increased supply of products drives prices down, which shifts firms short-term labour demand curve from LD_1 to LD_2 . To cover their labour costs (i.e. reach the point where $MRP_L = W$) each firm must now reduce the amount of labour it utilizes to E^* . The solid line in Figure 3 connecting E with the new equilibrium at E^* is the market labour demand curve. This reflects the impact of both the initial firm-level effect and the resulting market-level effect that must be taken into account when considering the total demand for labour.

Figure 3. Market Labour Demand Curve



The sensitivity of this inverse relationship between labour demand and wages is determined by demand elasticity (ϵ) which represents the percentage change in labour demand for a given percentage change in wages. If $\epsilon = 0$ then labour demand is not affected by a change in wages, and is said to be *perfectly inelastic*; where $0 < \epsilon < 1$ labour demand only slightly changes in response to a change in wages, and is said to be *inelastic*; and where $\epsilon > 1$ labour demand changes is said to be *elastic*.

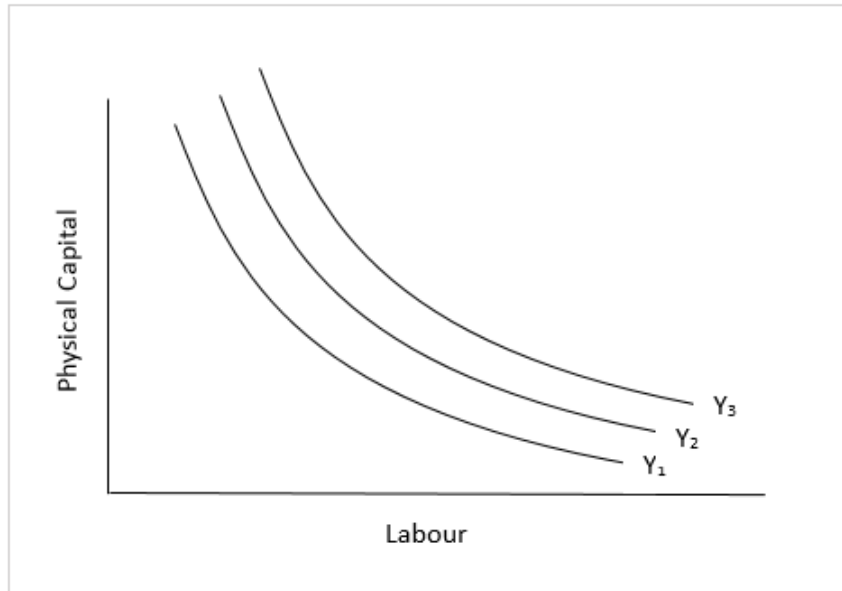
2.2 Labour Demand in the Long-Run

In the long-run a firm still faces the question of how to determine the optimal amount of labour to utilize, but they are also able to alter levels of physical capital as well. Thus, a firm must in the long-run determine the optimal mix of labour and physical capital to maximize profits.

The MPLD models the optimal choice with two factors of production in Figure 4. The goal is to minimize costs given all the potential combinations of physical capital and labour. The isoquant curves depict for a given level of technology the combinations of

physical capital and labour can be used to produce a given output.⁵ The curve is bent inward due to the diminishing marginal rate of technical substitution (MRTS). A diminishing MRTS indicates that, holding output constant, the reduction in labour that occurs with each additional unit of physical capital is decreasing.

Figure 4. Isoquant Curves

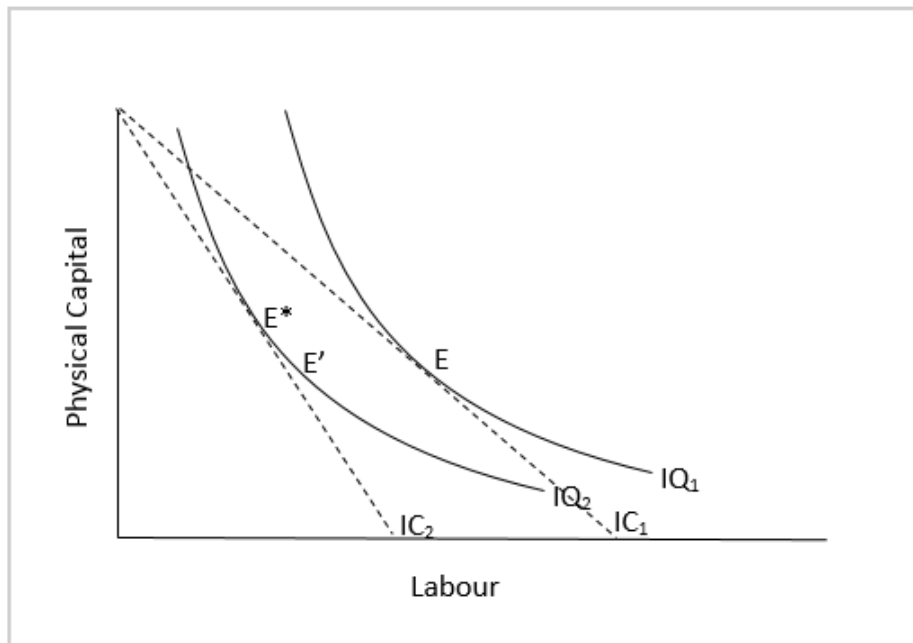


The diagonal lines IC1 and IC2 in Figure 5 are isocost curves. These lines represent the possible combinations of physical capital and labour that can be purchased for a given total cost. Thus, it depicts the relative costs of inputs. If a firm's budget for inputs changes, and the price of physical capital and labour remain the same, the isocost line shifts outwards in parallel, indicating that the firm can now purchase more of both inputs. If the price of labour increases, the firm can now only afford a reduced amount of labour. This is represented by a change in the slope of the isocost curve from IC₁ to IC₂, reflecting that the relative prices of the inputs have changed (Figure 5).

⁵ Some productions require fixed proportions of labour and physical capital but these exceptions are not important for the present purposes.

In the long-run the firm's wants to produce the largest level of output for the lowest cost. To achieve this, the firm selects the mix of physical capital and labour on the highest isoquant that is tangent to its isocost line (Figure 5, points E and E*).⁶ This point is where firms utilize the lowest-cost mix of inputs to produce the highest possible amount of output at the given level of technology, and so determines firms' labour demand in the long-run.

Figure 5. Equilibrium Mix of Inputs in the Long-Run before and After Wage Change



A change in conditions such as an increase in wages will cause firms to adjust the ratio of inputs in order to maintain profitability. The adjustment process in the long-run occurs in two steps. First, firms respond in the short-term by cutting production and employment, with physical capital remaining the same (Figure 5, point E to E'). Second, firms in the long-run adjust the mix of physical capital and labour to produce the largest level of output at the lowest cost (Figure 5, point E' to E*).

⁶ More specifically, the point on the isoquant line representing this choice is where the MRTS is equal to the ratio of wages and the cost of physical capital on the isocost curve, i.e. $MRTS = (W/R)$

The long-run labour demand curve is the line that connects point E and E*. This is because although there are short-term fluctuations in labour demand, in the long-run it is the lowest cost mix of physical capital and labour that determines demand. One implication of this adjustment is that long-run labour demand is more elastic than short-run labour demand. That is, the percentage change in labour demand in response to a percentage change in wages is greater in the long-run because firms can potentially replace labour with physical capital.

There are a series of factors that influence the long-run elasticity of labour demand. The first is consumer sensitivity to price changes – the less consumers are willing to accept higher prices for a product, the more elastic labour demand tends to be. This is because firms are less willing to pass on increased labour costs to consumers and so reduce labour costs instead. The second is the share of labour costs as proportion of a firms' total costs – the greater labour's share of costs is the larger the impact of wage changes on firms will be. The third factor is the substitutability of physical capital for labour – this topic is dealt with in the section 2.3.

2.3 The Role of Technological Change

The most important factor in the long-run dynamics of labour demand is technological change. The MPLD holds that technological innovation impacts production processes through the creation of more efficient production methods. Labour demand can fall either due to increasing labour productivity or substitution by physical capital. A reduction in physical capital occurs when old equipment is replaced by more productive new equipment. These changes are represented graphically by an inward shift of a firm's isoquant for the same amount of output. Thus, the implementation of new production technologies can result in the same output using less labour, and so an increase the ratio of physical capital to labour.

This appears to imply that technological change must lead to continuously falling labour demand. According to the MPLD, however, this is incorrect. Decreased labour demand is only the immediate impact of the implementation of new technology. By implementing new technologies firms lower their production costs, leading to a reduction in the price of the good being produced. At lower prices, demand for the good

increases, which results in the firm hiring more labour to meet the increased demand. Therefore the short-term decline in labour demand is offset by consumer demand-driven increases in labour demand.

The model makes two assumptions about the market for the good. First, that consumers are sufficiently sensitive to the price of the good for demand to increase after a reduction in prices; and second, that the market for the good is a competitive one where firms will pass costs-savings on to consumers in the form of lower prices. If these conditions do not hold, then a net decrease in labour demand can occur after the introduction of new technologies. Even in this case, however, a net decrease in *market* labour demand is not implied. Declining production costs and/or prices translate into increased incomes for consumers, which leads to increased product demand in other industries. Therefore, even if technological change produces a net decrease in labour demand in one industry, the result can be offset by increases in labour demand in other industries. This implies that the net effect of technological change in the long-run is increased employment opportunities.

To summarize, the MPLD describes how adjustments in labour demand differ in the short- and long-run, and the impact of technological change. Three important implications of the theory follow: first, short-term labour demand can run both counter to or with long-term trends in labour demand; second, that long-term labour demand will fall in industries where physical capital can easily substitute for labour; and third, that falling labour demand in one set of industries is compensated for by increasing labour demand in other industries, preventing persistent increases in unemployment.

The next chapter examines empirical evidence from Canada to determine if the implications of the MPLD are supported, or if significant long-term automation-driven decreases in market labour demand are possible.

3. Technology and Labour Demand

In this chapter, empirical data from Canada on the interaction between technology and labour is examined to determine if it is consistent with the neo-classical theory of labour demand. First, changes in industry-level capital-labour ratios are compared to changes in national unemployment rates between 1970 and 2008; next, changes in industry-level shares of total employment in Canada for the same period are examined; and finally, the three implications that emerge from the neo-classical theory of labour demand are assessed with respect to the empirical evidence.

3.1 Changing Capital-Labour Ratios and Unemployment

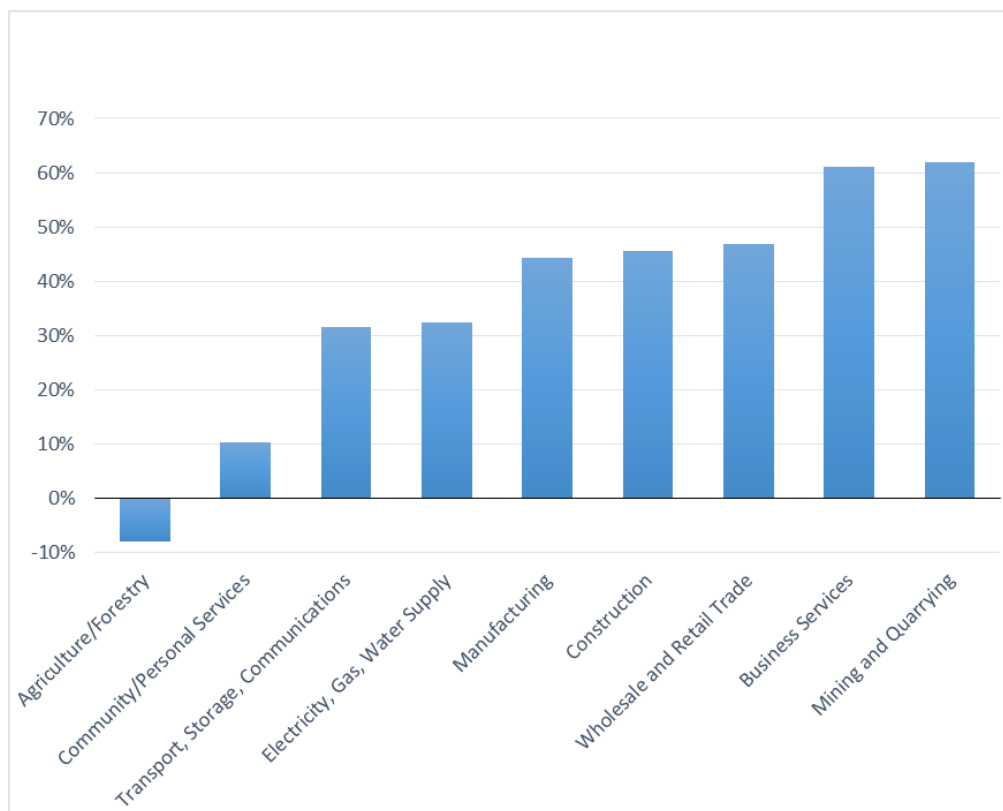
Firms in the long-run alter the mix of physical capital and labour in production processes in order to minimize costs. The mix of physical capital and labour can be represented as a capital-labour ratio (CLR). An unchanging CLR in the long-run is evidence of unchanging technology in production processes, while an increasing CLR is evidence for new technologies in production processes. Examining how industry-level CLRs have changed over time in Canada provides an indication of changes in per-unit labour demand. Comparing these to the unemployment rate over the same period provides a rough test of the implications of the neo-classical theory of labour demand.

CLRs are calculated here as the ratio of annual gross fixed capital volumes to annual employment. Figure 6 displays the total percentage change in the CLRs for nine industrial categories in Canada between 1970 and 2008. Substantial increases occurred in Mining (62%), Business Services⁷ (61%), Wholesale and Retail Trade (47%), Construction (46%), Manufacturing (44%), Electricity/Gas/Water Supply (32%), and Transportation, Storage, and Communications (32%). Community/Personal Services

⁷ Business Services corresponds to the OECD category of 'Finance, Real Estate, Insurance, and Business Services'

experienced a modest increase of 10%. Agriculture/Forestry is the only industry with a falling CLR (-8%). The magnitude of the increases in most industries is strong evidence for significant technological change in production processes over this period.

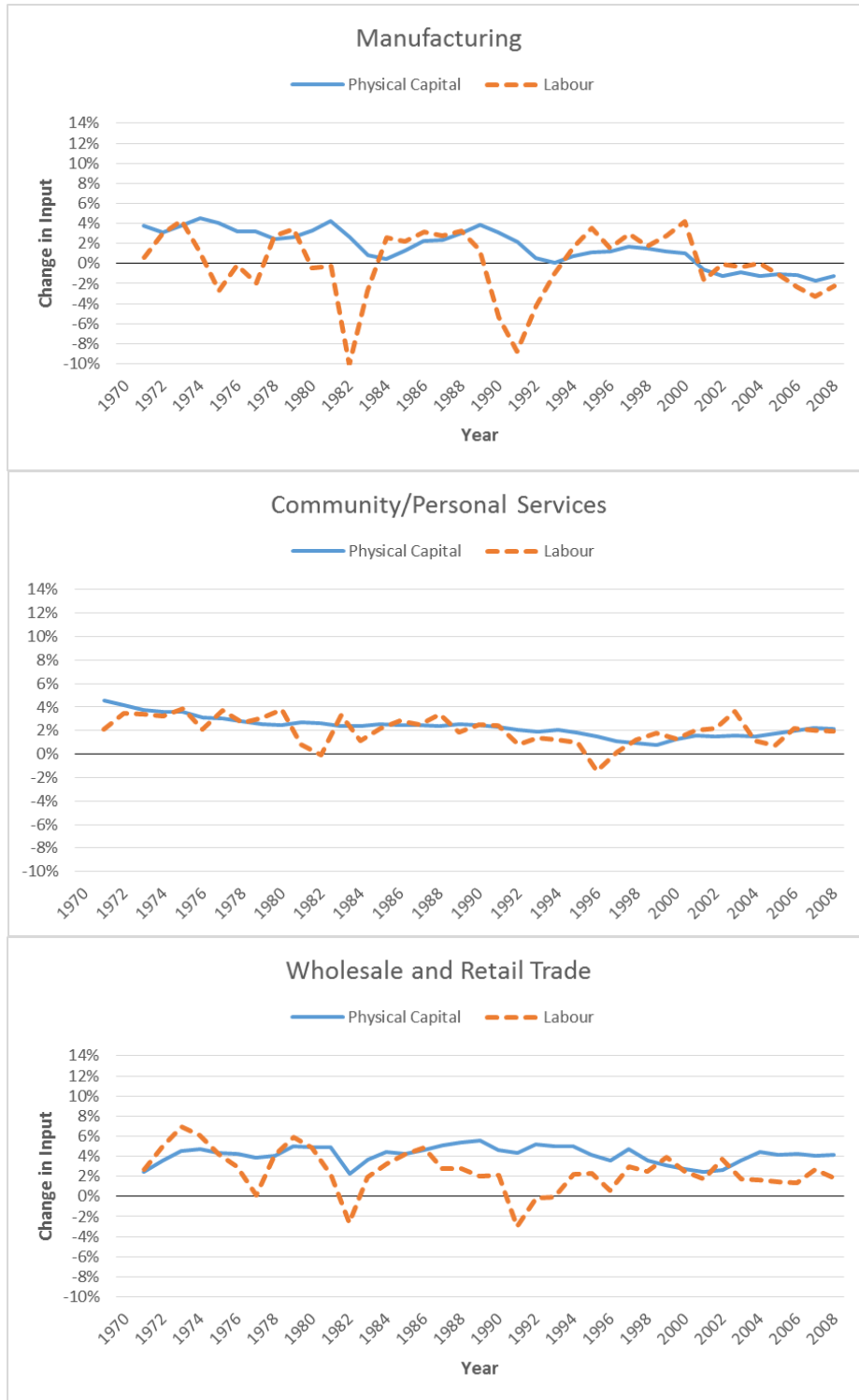
Figure 6. Total Change in Capital-Labour Ratio by Industry in Canada (1970 – 2008)

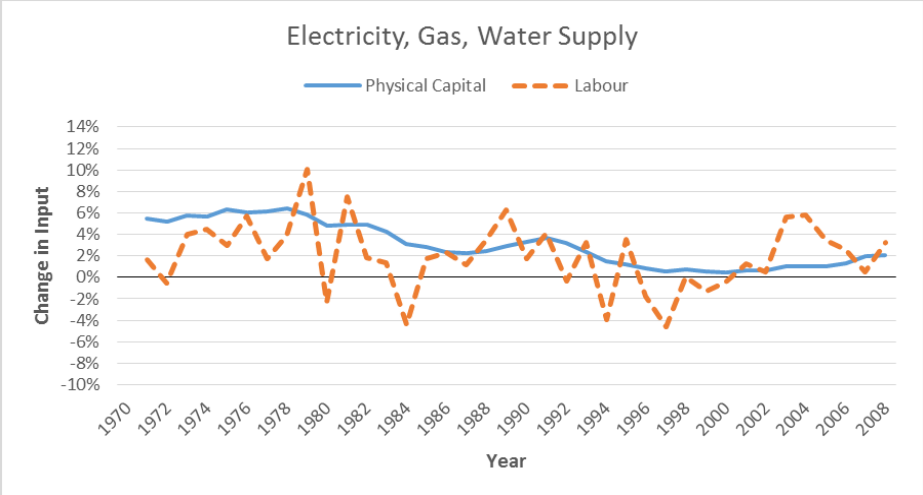
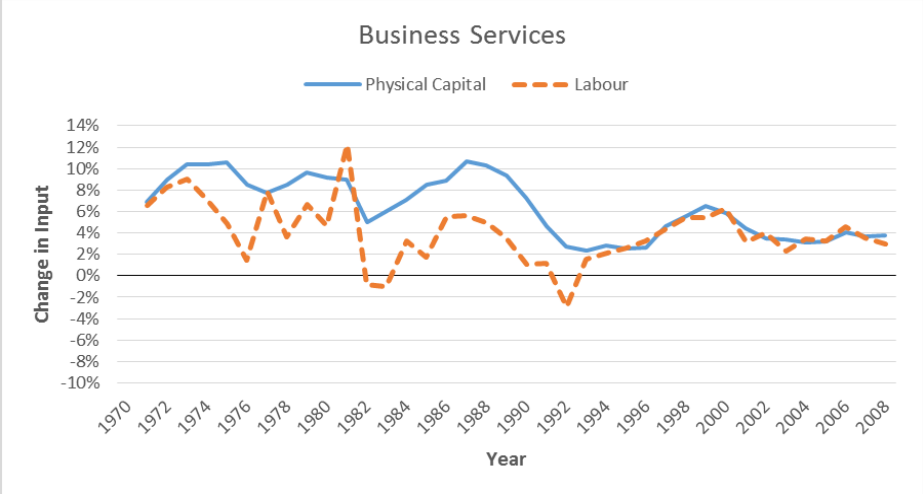
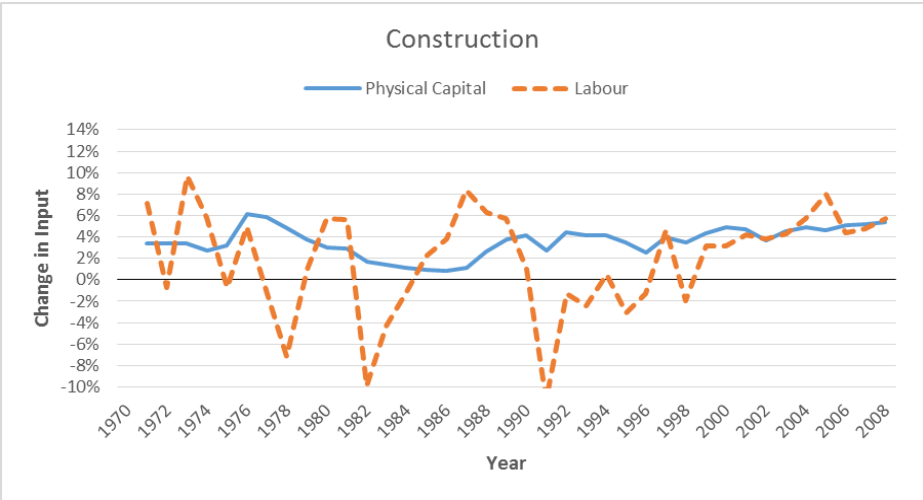


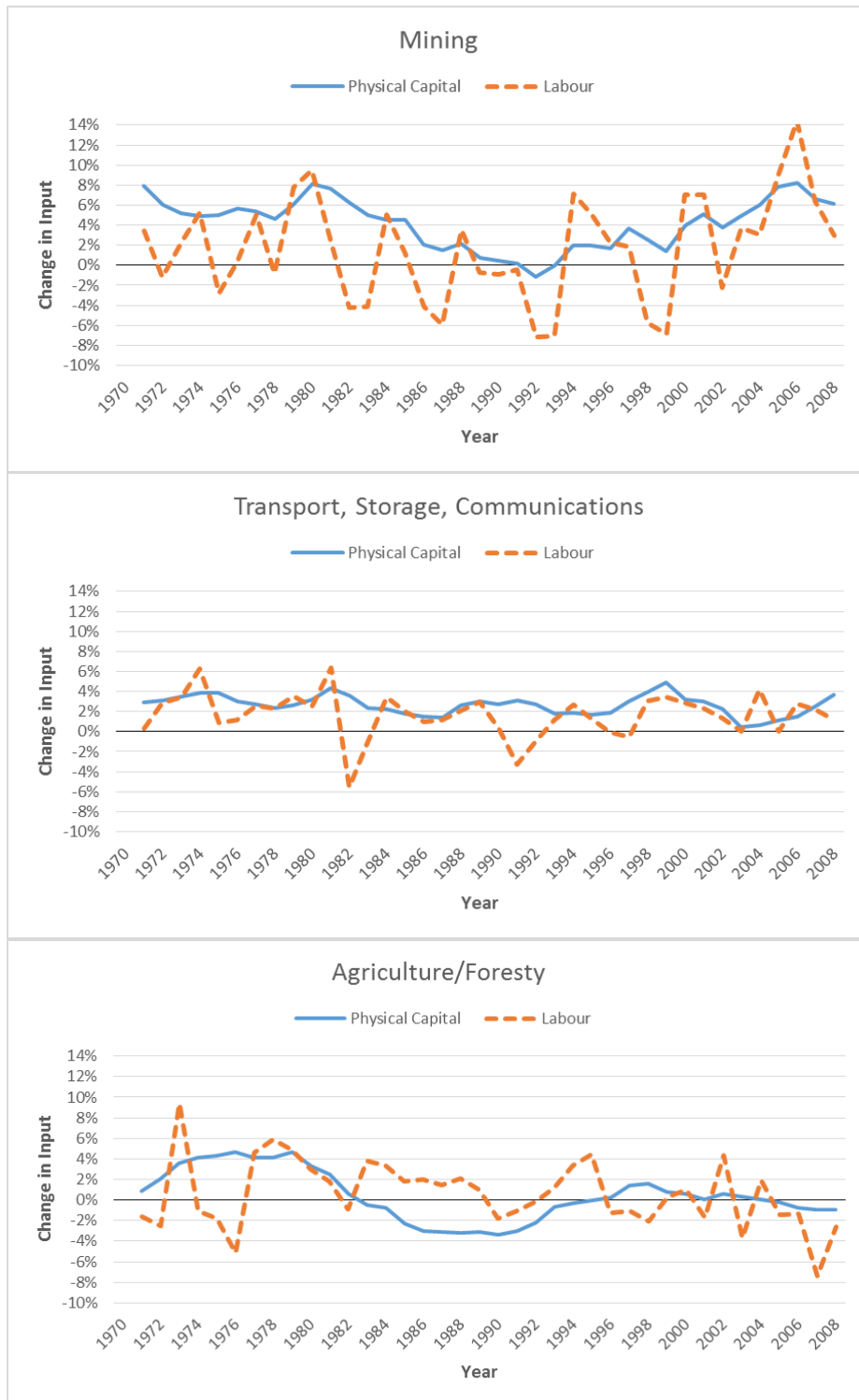
Source: OECD (2014a), author's calculations

Figure 7 separately compares annual changes of gross capital stocks and labour by industry over the period 1970-2008. Two features of these changes are worth noting. First, changes in labour input are significantly more volatile than changes in physical capital stocks, with rapid expansions and contractions occurring throughout the sample period. Second, with the exception of Agriculture/Forestry and Manufacturing (and for a very brief period, Mining) all industries show continuous growth in stocks of physical capital. The combined effect of these two patterns is an increasing CLR in most industries.

Figure 7. Annual Change in Physical Capital and Labour Inputs by Industry in Canada (1970-2008)



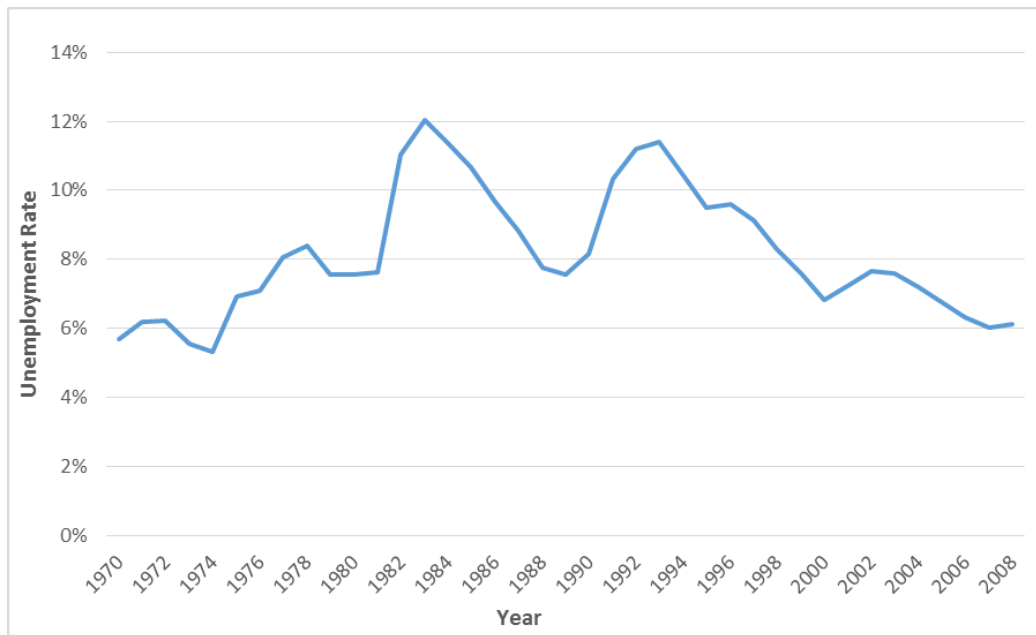




Source: OECD (2014a), author's calculations

Widespread increases in CLR between 1970 and 2008 do not appear to have produced increases in unemployment (Figure 8), with unemployment at 5.7% in 1970 and 6.1% in 2008. Over this period the rate fluctuated between a minimum of 5.3% in 1974 and maximum of 12% in 1983. These fluctuations mostly represent recessionary (e.g. early 1980's, early 1990's) and expansionary (e.g. mid-80's, later-90's) periods. No trend of sustained increases in unemployment over this period is observed

Figure 8. Canadian Average Annual Unemployment (1970-2008)



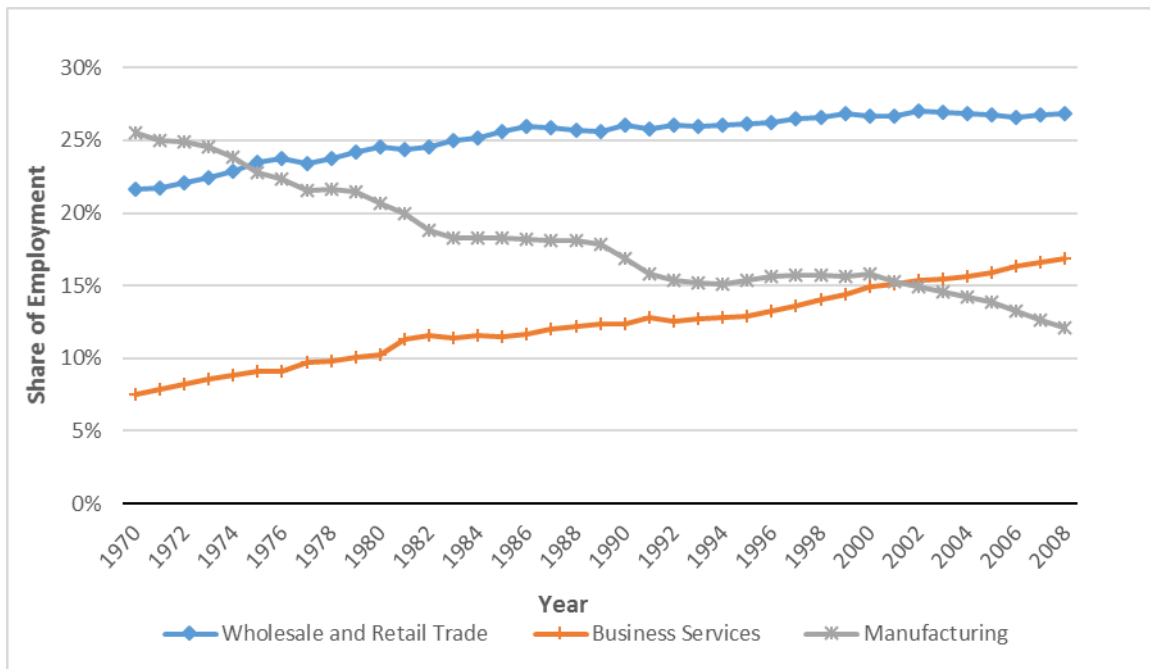
Source: OECD (2014b)

3.2 Changes in the Distribution of Labour

Significant changes in the distribution of labour occurred between 1970 and 2008. The only industry that experienced a significant decrease in labour share was Manufacturing (Figure 9). In 1970 Manufacturing was the second largest industry by labour share, with 25% of total employment. By 2008 the figure had fallen to 12%. The decline is relatively steady throughout the period, although there was some stability in the 1990's.

Wholesale and Retail Trade, and Business Services experienced significant increases in labour share (Figure 9). In 1970 Wholesale and Retail trade employed 22% of the labour force, the third-largest industry by labour share. In 2008 its share of labour had risen to 27%, making it the second-largest. The industry saw rapid increases in the late 1970's, but slowed over time before becoming flat in the 21st century. In 1970 Business Services accounted for approximately 8% of the labour force, the fourth largest industry by labour share. By 2008 its share had more than doubled to 17%, becoming the third-largest. The increase has been steady over the entire period, with indications that it is accelerating in the 21st century.

Figure 9. Share of Canadian Employment by Industry (1970 – 2008)

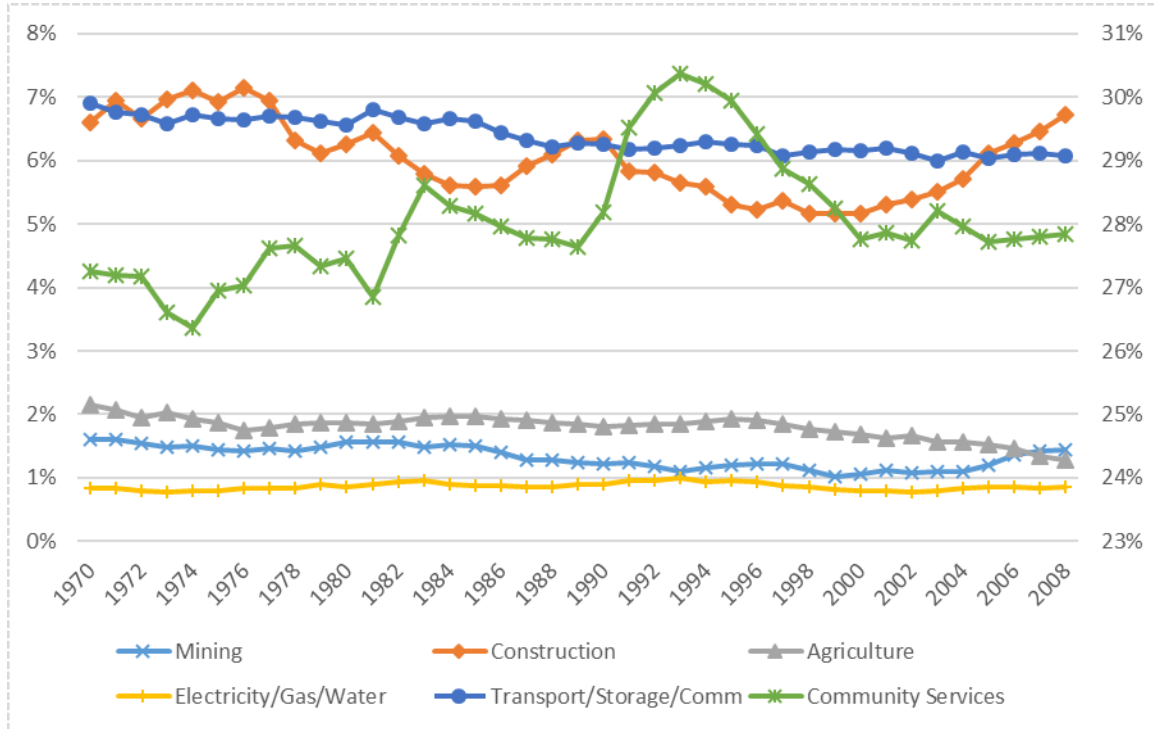


Source: OECD (2014a), author's calculations

All other industries experienced only minor changes in shares of labour over this period, including Community and Social services, which was the largest industry by labour share at 28% in 2008. Its share of total employment has been relatively stable, fluctuating between roughly 27-30% since 1970 (Figure 10). In combination, all other industries made up 18% of the labour force in 1970, declining to 16% in 2008 (Figure

10). Changes in labour share in each of these industries was within plus or minus 2% over the period measured.

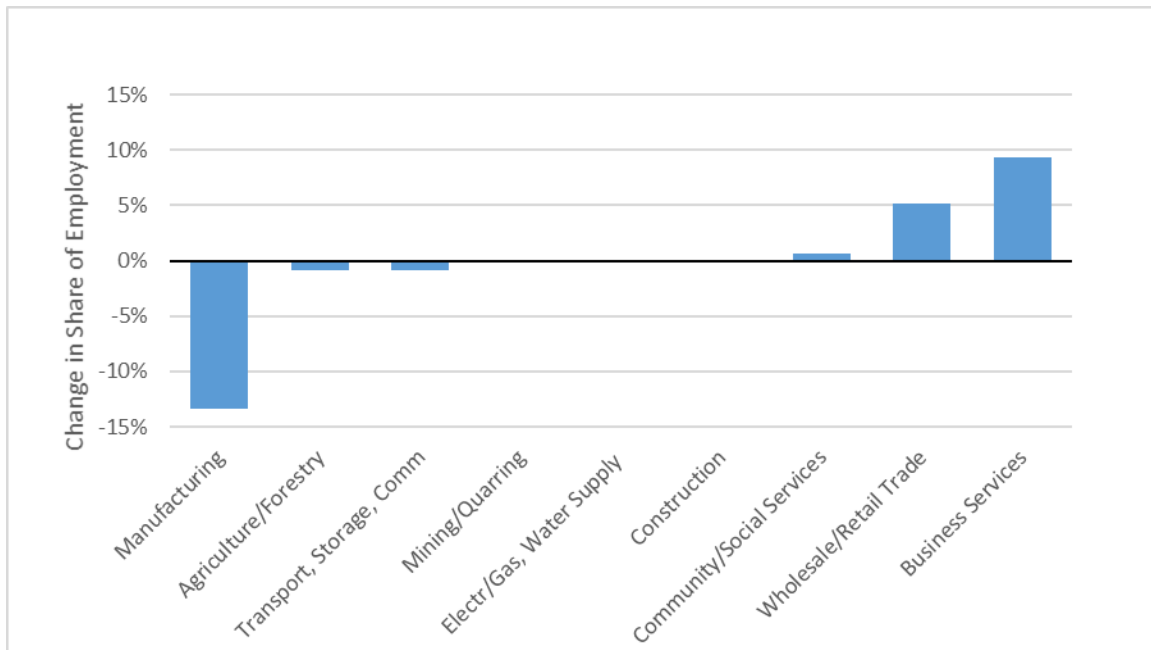
Figure 10. Share of Canadian Employment by Industry (1970-2008) - Others



Community Services on right axis – all others to left axis
 Source: OECD (2014a), author's calculations

The pattern that emerges between 1970 and 2008 is a large decrease in the share of total employment in Manufacturing, coupled with significant increases in shares of total employment in Wholesale and Retail, and Business Services (Figure 11). This pattern of labour reallocation appears to have mitigated any long-term increases in unemployment.

Figure 11. Change in Share of Canadian Employment by Industry (1970-2008)

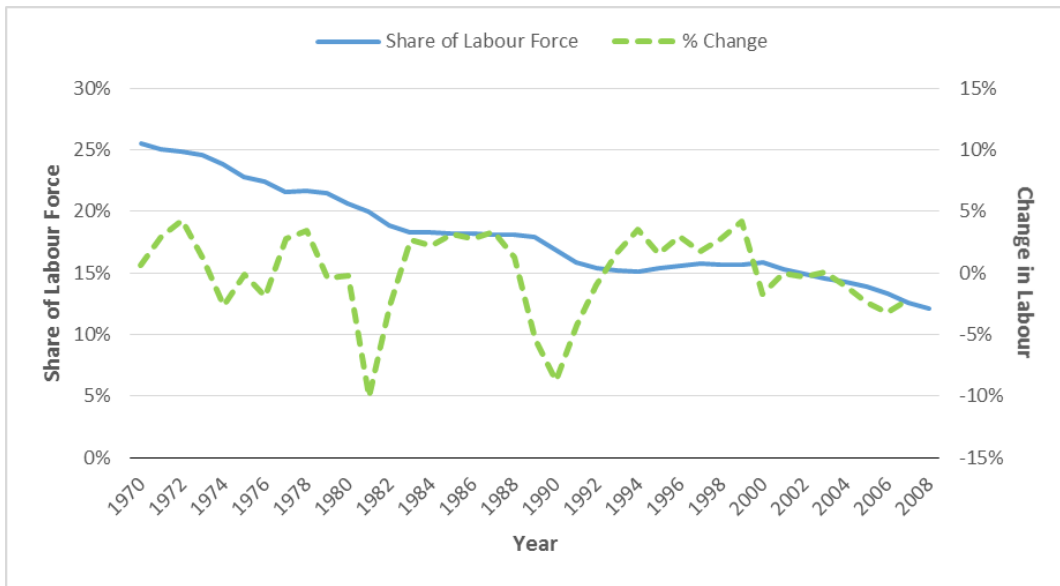


Source: OECD (2014a), author's calculations

3.3 Evaluation of the Marginal Productivity Theory of Labour Demand

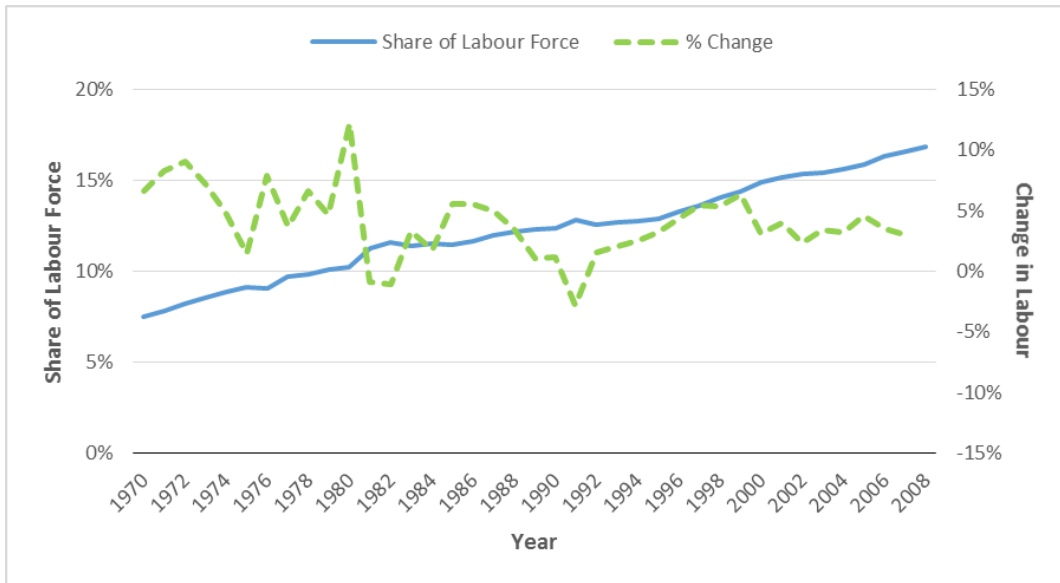
The first implication of the Marginal Productivity Theory of Labour Demand (MPLD) is that short-run fluctuations in labour demand will run both with and counter to long-run trends in labour demand. The evidence in the previous section supports this claim. Clear examples of the short-run variability of labour demand over a larger trend are seen in Manufacturing and Business Services. Labour demand in Manufacturing saw two periods of declines of roughly 10%, as well as periods where labour increased by 2.5-5% annually (Figure 12). However the long-run trend, as previously discussed, was a sustained decline from 25% to 12% of the labour force. A similar pattern is seen in Business Services, with extended periods of double-digit labour demand increases over the previous year, as well as two small periods of decline that correspond to recessionary periods (Figure 13). Thus, the proper scope for assessing the full employment impact of technology is the long-run.

Figure 12. Share of Employment and Annual Change – Manufacturing



Source: OECD (2014a), author's calculations

Figure 13. Share of Employment and Annual Change – Business Services



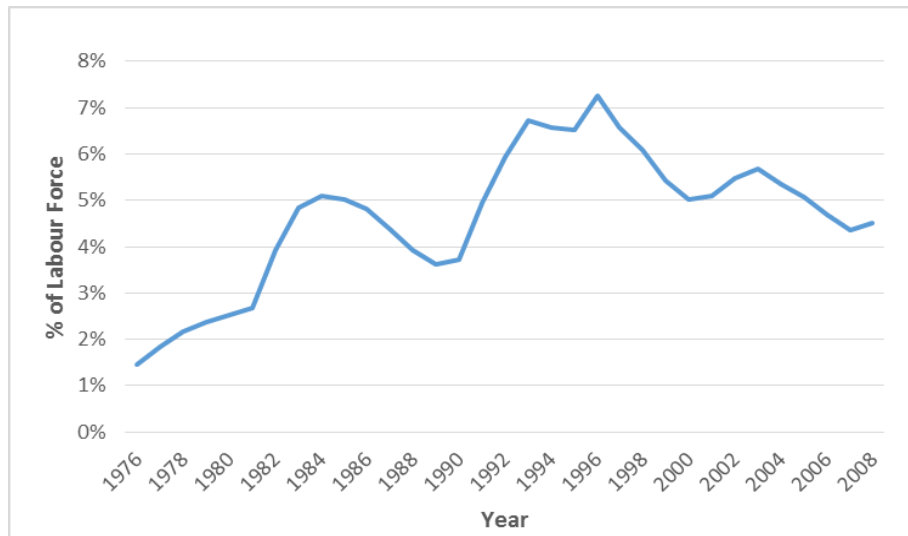
Source: OECD (2014a), author's calculations

The second implication of the MPLD is that long-run declines in labour demand will occur in industries physical capital easily substitutes for labour. This implication is consistent with the evidence as well. A large number of labour substituting technologies have emerged since the 1970s in manufacturing, e.g. design and engineering, processing/fabrication/assembly, materials, handling, inspection, network communications, and integration and control (Sabourin and Beckstead, 1998). The adoption of these technologies coincides with decreasing labour demand over the sample period. Although many novel technologies were also introduced into Business Services, and Wholesale and Retail trade over this period, these technologies tended to complement labour rather than substitute for labour – for example, information and communication technologies. The employment impact of increasing CLR's in Business Services, and Wholesale and Retail Trade was therefore very different than in Manufacturing, as the changes in shares of labour in Figures 12 and 13 suggest. This evidence is consistent with the second implication of the MPLD, although, importantly, the theory does not make clear what allows some technologies to be labour substituting and other labour complementing.

The third implication of the MPLD is that declining labour demand in one set of industries is offset by increases in labour demand in other industries, preventing long-term increases in unemployment. The reallocation of labour from Manufacturing to Business Services, and Wholesale and Retail since 1970 confirms that automation-driven declines in labour demand in one industry can be offset by increases in others. However there is some evidence that this relationship is weaker than what the unemployment data suggests. First, involuntary part-time labour as a percentage of the labour force has risen from 1.5% in 1970 to 4.5% in 2008, with a maximum value of 7.5% during the mid-1990's (Figure 14).⁸ This suggests a possible decline in labour demand since 1970.

⁸ Involuntary part time labour is defined as worker that would like to work in a full-time position but are only able to find part-time work

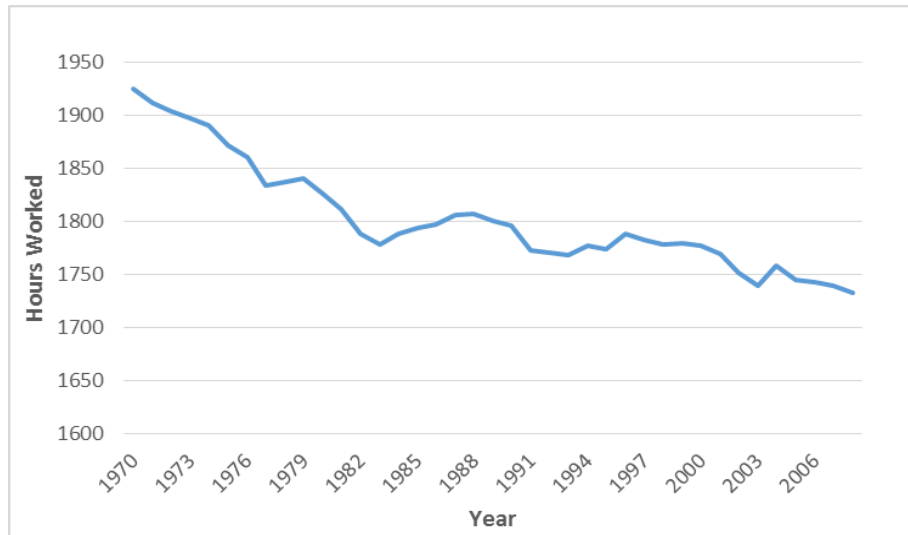
Figure 14. Involuntary Part-Time Employment Rate



Source: OECD (2014c), author's calculations

Second, average annual hours worked in Canada declined by 10.5% between 1970 and 2008 (Figure 15). On this measure there has been a decline in labour usage intensity, which suggests a decline in labour demand. Therefore, although the data generally supports this implication of the MPLD, but there is evidence that the support for the claim is weaker than it seems.

Figure 15. Average Annual Hours Worked - All Industries



Source: OECD (2014d)

In summary, the MPLD explains much of the dynamics of labour demand in the last quarter of the 20th century and first decade of the 21st. However there are phenomena related to technological change and labour demand that remain unexplained. The first is the specific pattern of labour reallocation from Manufacturing to Business Services and Wholesale and Retail Trade in the context of increasing CLRs between 1970 and 2008. The pattern is consistent with the MPLD, but the theory does not explain it. The second is the long-run decline in average annual hours worked, and the long-term increase in involuntary part-time work in Canada since 1970. These suggest long-run declines in labour demand, which conflicts with the MPLD. The next chapter examines contemporary evidence and signals that these phenomena are increasing in magnitude as a result of increasingly sophisticated automation technologies.

4. Technology and Unemployment

For automation-driven unemployment to be a concern, increasing numbers of occupations not previously susceptible to automation would need to become susceptible. In the period 1970-2008 demand for labour in Manufacturing declined significantly, while demand for labour in Business Services and Wholesale and Retail Trade increased significantly, thereby mitigating sustained increases in unemployment. However there is evidence of softening labour demand. In this chapter I first discuss the type of unemployment that is of concern. Second, I outline recent empirical evidence for the spread of automation into Business Services and Wholesale and Retail Trade, as well as contemporary signals that many occupations in these industries are facing automation in the near future. Finally, I discuss a potential objection to the conclusions in this section.

4.1 Types of Unemployment

Automation-driven unemployment is a form of structural unemployment. As increasing numbers of occupations become susceptible to automation, a growing share of the labour force will possess skills that are no longer demanded by employers, and will have few options for re-employment. The next section looks at contemporary evidence and signals for this pattern.

4.2 Recent Empirical Evidence for Spreading Automation

Recent research in Canada and other developed countries finds evidence for automation-driven declines in labour demand for certain types of occupations in service industries. Autor and Dorn (2013) find evidence of falling demand for labour in administrative support, clerical, and sales occupations in the United States over the period 1980-2005 and rising employment shares in low-skill customer service and manual-labour related occupations. They attribute this pattern to the recent spread of

automation technologies into low-skill office-based occupations. Beaudry, et al. (2013) also find a decrease in demand for labour in similar occupations starting in 2000 and similarly note that this pattern "...is now commonly interpreted as reflecting the replacement of such jobs by technological advances (robotics and information technology) and offshoring". Green and Sand (2014) find a similar pattern in Canada, with declining demand in secretarial and clerical occupations starting in the 1990s. Thus there is widespread evidence that the demand for labour in low-skill office-based service occupations is experiencing a pattern of technology-driven decline similar to the one that began in the 1970's for Manufacturing.

4.3 Further Signals of Spreading Automation

There are many recent examples of firms implementing technologies that substitute for low-skill customer service occupations. In May of 2011 the fast-food chain McDonalds introduced touchscreen ordering kiosks at locations in the UK that allow customers to input orders and pay for them without interacting with a clerk (Jackson, 2011). The success of this program has led the company to explore implementation in North America as well (Kedmey, 2014). In a similar move the restaurant chains Applebees and Chilis have started installing computer tablets in tables at their locations to allow ordering and paying without interacting with wait-staff (O'toole, 2014). In the healthcare sector, medical transcriptionists at the Ottawa Hospital in Ontario were laid off in 2012 and replaced with speech-to-text transcription software (Cameron, 2012). The University of Pittsburgh Medical Center pursued the same policy, laying off 128 transcriptionists to be replaced with speech-to-text software (Twedt, 2013). In November of 2014 a private security firm in San Jose, California rolled out a mobile autonomous security robot that can be rented for \$6.25 an hour, well below minimum wages anywhere in most developed countries (Fox, 2014). In logistics and warehousing, the online retailer Amazon deployed 10,000 automated robots in 2014 to work in its distribution centres retrieving items from shelves and bringing them to packing centres, duties previously carried out by warehouse personnel (Cardinal, 2014).

Some high-skill labour has also begun to be impacted by automation technologies. The investment bank JP Morgan announced that it will be cutting 17,000

jobs by the end of 2014 in a bid to restructure and automate certain services (Henry, 2013). Part of the cuts include 6,000 tellers and related staff at branch offices, to be replaced with interactive machines capable of handling everyday banking transactions for customers. The UK bank Lloyds is following suit, laying off 9,000 workers and closing 150 branches partly in a bid to automate its everyday banking services (Treanor, 2014). In Canada Scotiabank cut 1,500 jobs and closed 120 branches with one goal being the automation of certain office functions as well (CBC, 2014). In India, the seventh largest IT services firm in the world Wipro has begun a three-year campaign to reduce the size of the firm by a third (Sood, 2014). Part of the campaign is the reduction of computer infrastructure monitoring and administration from 48,000 to 12,000 workers through the implementation of automated software tools. In the western United States, negotiations between dockworkers/shippers and terminal owners is focused on the impact of automation technologies on the workforce, with robotics technologies expected to replace half of the 20,000 dockworkers in coming years (Nash, 2013). In the entertainment industry, the videogame developer Blizzard Entertainment laid off 600 customer service staff in 2012 after the implementation of automated customer service programs (McElroy, 2012).

Two considerations emerge from these signals. First, automation technologies that can replace labour in both low- and high-skill occupations are being developed and implemented. Second, these technologies are being implemented across a variety of industries and countries. I have restricted the examples above to include only instances where layoffs have occurred or are imminent. Not included are the large number of in-development technologies that are expected to impact employment in many other occupations in the future, such as automated vehicles and algorithms for automated research. Therefore the examples represent only a small subset of impacts that are likely to occur in the near future.⁹ Nevertheless they provide support for predictions of

⁹ For example, a recent report from a UK consultancy firm predicts that artificial intelligence will replace human labour entirely in legal research professions by 2030 (Bindman, 2014) – evidence supporting this prediction can be seen in a recently begun project at the University of Toronto that aims at training an IBM supercomputer to make legal recommendations using information in legal databases (Gray, 2014).

increasing automation across the skill-distribution, and so of the increasing risk of significant automation-driven structural unemployment in the near future.

4.4 Spreading Automation and Structural Unemployment

Given the evidence of large-scale labour reallocation between 1970 and 2008 in Chapter 3, the above conclusions face the following question: If labour reallocation prevented significant increases in structural unemployment in the past, won't a similar phenomenon occur in the future as new automation technologies spread? This point is strengthened by an earlier labour reallocation from agriculture to manufacturing in the first half of the 20th century.

There are, two aspects of spread of automation technologies that potentially differentiate it from past episodes. The first is pace. Although difficult to measure, there is some evidence that it appears to have been accelerating since the early 20th century, and it is expected to continue accelerating in the future (Economist, 2012; OECD, 1998). This raises the possibility that occupations will become susceptible to automation at a much faster rate than in the past, leaving an increasing number of workers with obsolete skill-sets. The second characteristic concerns the skill-level of occupations that are most at-risk for automation in the near-future and occupations that will likely remain in demand. In past episodes of labour reallocation, from agriculture to manufacturing, and manufacturing to service industries, large numbers of workers transitioned from low-skill occupations in one industry to low-skill occupations in another. However, as sections 4.2 and 4.3 indicate, automation technologies appear to be greatly reducing the need for low-skill labour of any kind. If this trend continues, more and more low-skill workers will need transition to occupations with much higher skill requirements in the future. Combined with the increasing pace of automation, many workers will likely be unable to adjust due to differences in natural endowments and access to education and training. Therefore automation-driven labour reallocation appears to face barriers that did not exist in previous episodes.

5. The Benefits and Costs of Automation

In this chapter I examine both the benefits derived from increasing levels of automation, as well as the costs associated with significant increases in structural unemployment.

5.1 The Benefits of Automation

The quantitative benefits of automation come from increases in productivity. Productivity increases are the most important factor behind increasing standards of living (Ragan and Lipsey, 2011, Ch.8). Increased productivity reduces production costs for firms as fewer inputs are needed to produce a given level of output. In a competitive market this results in lower prices for consumers as firms attempt to capture greater market share. Thus widespread automation in competitive markets benefits consumers with of lower prices for goods and services, and so increases in real income.

The qualitative benefits of automation are difficult to summarize as they tend to be technology-specific. One class of qualitative benefits relates to the quality of the work performed by automation technologies compared to human labour. For example, one of the main advantages of software is a lack of bias – people must satisfy biological imperatives such as sleeping and eating that can reduce performance (Frey and Osborne, 2013). Another example concerns the volume of information that automated systems can process and analyze without the cognitive limitations that human labour entails. Medical diagnostics software that can cross-reference patient information with millions of pages medical reports, trials, journal articles, and patient records have already been implemented (Frey and Osborne, 2013). Such information-checking capabilities are far beyond human abilities, and could result in more accurate diagnoses. A second class of qualitative benefits relates to safety. Automated vehicles, although still in their infancy, have the potential to be much safer on the road through the use of advanced sensors, faster reaction times, and immunity to distraction (Frey and Osborne,

2013, p.20). In the United States, transportation incidents alone accounted for 40% of fatal occupational injuries in 2013 (Bureau of Labour Statistics, 2013). This suggests that enhanced safety would therefore be an enormous qualitative benefit of widespread automation.

5.2 The Costs of Automation

A central characteristic of structural unemployment is its extended duration. Research has identified a variety of monetary costs associated with long-term unemployment. The most direct is loss of income and declining consumption. Research by Johnson and Feng (2013) find that after the 2009 recession, family incomes for the long-term unemployed dropped by 40% or more. Browning and Crossley (2001) find that after six months, families of unemployed workers reduce consumption by 16-24% depending on whether the unemployed worker was the only source of income for the family or not. In the context of high levels of unemployment these impacts could significantly dampen economic growth.

The second monetary cost of long-term unemployment is reduced re-employment wages and job stability (Nichols, et al. 2013, p.4). Stevens (1997) finds that the long-term unemployed are also more likely than other workers to leave new jobs. Thus, decreased job attachment could also have impact on economic growth through decreased levels of consumption.

There are also a wide variety of non-monetary costs associated with long-term unemployment. From the standpoint of the individual, there is strong evidence that long-term unemployment has serious adverse impacts on health. Although evidence about the impact of long-term unemployment on self-reported health is mixed (Nichols, et al, 2013, p.9), evidence of increased mortality is not. Sullivan and von Wachter (2009) find a 10-15% increase in death rates in the twenty years after displacement from the workforce. Geewax (2011) reports that long-term unemployed people after the 2009 recession were more than twice as likely as employed people to skip dental visits, defer medical care, and not fill prescriptions. Lack of preventative medical care could increase healthcare system costs.

Studies also find that long-term unemployment for parents has adverse impacts their children's grades (Stevens and Schaller, 2011), their probability of finishing school (Wightman, 2012), and their earnings in later life (Oreopoulos et al. 2008). Lindner and Peters (2013, as cited in Nichols, et al. 2013, p.11) find that unemployment also has adverse impacts on family stability. Similarly, McLoyd, et al. (1994) find that unemployment-related financial stress is linked to adverse assessments of interactions between mothers and their children, as well as depressive symptoms in adolescents.

In summary, there are a number of qualitative and quantitative benefits and costs to spreading automation. However, determining whether the benefits outweigh the costs will require data on both changes in the structural unemployment rate due to automation, as well as the gains in real income driven by automation. A study to provide quantitative estimates of the impact of automation-driven structural unemployment is highly desirable. However it is beyond the scope of the current essay.

6. The Policy Problem

The policy problem I analyze in my study can be expressed by the following statement: The susceptibility of an increasing number of occupations to automation could lead to historically high levels of structural unemployment in Canada in coming decades.

The ongoing development of automation technologies in recent decades has led to the substitution of physical capital for labour in an increasing number of occupations. As the pool of occupations not susceptible to automation shrinks, economic growth will produce weaker increases in aggregate labour demand. Hence, the coming decades may see too few jobs created to offset jobs lost in occupations that have been automated. The result would be increasing structural unemployment, which is associated with a number of economic and social costs. It is therefore necessary to evaluate the potential magnitude of job losses in order to assess policies to mitigate these costs.

The major stakeholders concerned with this broad economic issue are the labour force, the federal government, and provincial governments. The labour force will be directly impacted by expanding automation, either through wage impacts, loss of employment, or diminished job prospects and long-term unemployment. The federal government will be impacted by increasing unemployment through decreased tax revenues and increased expenditures on social assistance either directly or through transfers to the provinces. Provincial governments will also be impacted by increasing unemployment through decreased tax revenues and increased expenditures on social assistance.

The minor stakeholders are firms and union. Firms are the primary agent of the spread of automation technologies through decisions on whether or not to implement them, and their performance affects economic growth. Unions represent workers in

some industries, and so are both affected by increasing rates of unemployment and able to act at a political level to influence policy.

7. Occupations, Tasks, and Skills

To estimate the potential future impact of automation on Canadian employment it is first necessary to evaluate the model underlying the estimations. I first describe the model and then check if it is consistent with changes in labour demand in Canada between 1970 and 2008.

7.1 The Task Model of Labour

My analysis rests on the Task-Model of Labour (TML) developed by Autor, et al. (2003), Goos and Manning (2007), and Acemoglu and Autor (2010). This model is based on three principles: First, occupations can be identified with bundles of activities referred to as ‘tasks’. Second, tasks fall into groups based on general characteristics (“task types”). Most versions of the model use the categories ‘routine’ and ‘non-routine’ on one axis, and ‘manual’ and ‘cognitive’ on the other axis (Acemoglu and Autor, 2010). Routine tasks can be codified as a set of explicit rules, while non-routine tasks require flexible problem-solving and communication that cannot be codified (Autor, 2013). Manual tasks require the physical manipulation of materials, while cognitive tasks involve analytical or interactive work (Autor, et al., 2003). The intersection of these categories produces four task-types: Routine-cognitive, routine-manual, non-routine-cognitive, and non-routine-manual.¹⁰ Examples of occupations related to each task-type are shown in Table 1.

¹⁰ Of course, few occupations contain tasks falling under only one of these four categories.

Table 1. Occupations by Task Type

	Cognitive	Manual
Routine	Bookkeeper Call-Center Operator	Warehouse Picker Repetitive Assembler
Non-Routine	Scientific Researcher Musician	Construction Labourer Electrician

Source: Frey and Osborne (2013)

Third, each of the four task-types corresponds to a skill-set required to perform occupational tasks. Routine-manual tasks, for example, require some minimal level of dexterity and the ability to remember instructions. Non-routine-manual tasks require the ability to navigate unpredictable environments, make independent judgements, and utilize specialized knowledge to interact with physical systems. Routine-cognitive tasks require the ability to repeatedly apply abstract rules or engage in structured interpersonal communications. Non-routine-cognitive tasks require the creative application of abstract reasoning and/or interpersonal communications to reach goals that are achievable in multiple ways with differing trade-offs.

The TML identifies occupations with tasks, tasks with task-types, and task-types with skill-sets. Technologies that perform some but not all tasks for a given occupation are labour-complementing, e.g. excavators and dump trucks on construction sites. Technologies that perform all tasks for a given occupation are labour-substituting, e.g. produce-sorting machines, food processing machines.

7.2 Applying the Model

To explain the changing pattern of labour demand in Canada between 1970 and 2008 that was shown in Chapter 3, the TML addresses two facts. The first is the large decrease in the share of total employment in Manufacturing in the context of an increasing capital-labour ratio (CLR). Many manufacturing occupations involve standardized, repetitive tasks with physical materials in controlled environments. These tasks fall under the task-type 'routine-manual', and require skills such as manual dexterity and memorization of instructions. During the last quarter of the 20th century

computer and robotics technologies grew increasingly sophisticated and took over larger role in production processes. The match between the types of tasks performed by labour in many manufacturing occupations and the technological capabilities developed over this period explains why an increasing CLR was accompanied by declining labour demand: a significant proportion of new physical capital was labour-substituting.¹¹ Evidence of this is found in a 1998 survey of large Canadian manufacturing firms, where 82% firms reported adopting programmable logic control machines, and 66% the implementation of robots in production processes (Sabourin and Beckstead, 1998).

The second fact to be explained is the large increase in share of total labour employed in the service sector (i.e. Retail and Wholesale Trade, and Business Services) in the context of increasing CLRs. Occupations in the service sector can involve personal interaction, the application of abstract rules, or manual interaction with products. They can also be either structured (e.g. running a checkout counter) or unstructured (e.g. wealth management). Service occupations are therefore categorized as routine-cognitive, non-routine-cognitive, or non-routine-manual. Between 1970 and 2008 developments in information and communications technologies (ICT) led to their increasing use in almost every sector. This is evidenced by the large increase of ICT as a proportion of total physical capital spending since the early 1990s (Jaumotte, et al. 2013). However, ICT has had only a limited ability to replace labour in routine-cognitive tasks, and it has no ability to substitute for labour in either non-routine-cognitive or non-routine-manual tasks. So, rising CLRs in the service sector were due almost entirely to the introduction of labour-complementing technologies. Thus the TML can explain industry-level shifts in labour demand through the differential introduction of labour-complementing and labour-substituting technologies in different industries.¹²

¹¹ Falling physical capital costs also played an important role in the adoption of automation technologies, but this is not within the scope of the present analysis.

¹² Technological change was not the only factor contributing to the shift of labour from manufacturing into services, but it is beyond the scope of this paper to address these other factors.

The TML also provides a partial explanation for the long-run decline in average annual hours worked and increase in involuntary part-time work in Canada since 1970.¹³ Productivity-driven declines in labour demand in one sector of the economy should stimulate labour demand in other sectors of the economy. However the magnitude of offsetting increases in labour demand in a given industry depends on the industry's labour-intensity – the less labour required in production processes, the smaller the offsetting increase in labour demand for a given decrease in another industry. Labour demand increases are therefore influenced by the capabilities and diffusion of technologies. Declining labour demand in the form of reduced labour intensity is implied by the TML as an increasing proportion of task-types become susceptible to automation.

To summarize, the TML provides an explanation for changes in industry-level labour demand in the context of widespread increases in CLRs between 1970 and 2008 in Canada. It also suggests how increasing CLRs could weaken demand for labour without causing sustained increases in unemployment. Having demonstrated the consistency of the TML with the evidence, I next describe work based upon the TML that estimates occupation-level probabilities for automation, and use these probabilities to estimate the number of Canadian jobs that are at high risk for automation over the next two decades.

¹³ This explanation is likely partial, as some researchers have found age-cohort effects (Barnett, 2007); however no definitive explanation for these trends appears to have emerged in the literature.

8. The Future Impact of Automation on Employment in Canada

In this chapter I estimate the potential impact of automation on Canadian employment over the next two decades. First, I briefly describe how researchers use the TML to calculate occupation-level automation probabilities. Second, I utilize these probabilities to estimate of the proportion of Canadian jobs that are at high risk for automation over the next two decades. Finally I consider some of the limitations of these findings.

8.1 Occupational Automation Probabilities

Using the TML, Frey and Osborne (2013) develop a procedure to assign probabilities to individual occupations that indicate their susceptibility to automation in the near future.¹⁴ Automation probabilities are assigned in two steps: first Frey and Osborne (2013), in consultation with machine-learning and robotics researchers, identify types of skills that are likely beyond the capabilities of current and near-future technologies. These 'engineering bottlenecks' are grouped into three categories (Table 2). Second, the researchers develop a program that analyzes the task-content of 703 current occupations for tasks that require skills falling into the engineering bottleneck categories.¹⁵ An automation probability is assigned to each occupation based on the degree to which occupational tasks require these skills: heavy reliance on these skills translates to a low automation probability assignment, while low reliance translates to a high probability assignment.

¹⁴ A probability of 0 means that the occupation is extremely unlikely to be automated in the near future, while a 1 means that the occupation is certain to be automated in the near future.

¹⁵ See Frey and Osborne (2013) for a technical overview.

Frey and Osborne (2013) organize their results into three categories of automation risk. Occupations with an automation probability between 0 and 0.3 are categorized as low risk - 33% of occupations fall into this category. Occupations with an automation probability between 0.31 and 0.7 are categorized as medium risk – 19% of occupations fall into this category. Finally, occupations with an automation probability between 0.71 and 1 are categorized as high risk – the remaining 47% of occupations fall into this category. The authors find that a large proportion of the occupations falling into the high-risk category are in services, sales, and construction.

Table 2. Engineering Bottlenecks to Near-Future Automation

Engineering Bottleneck	Skill-Types
Perception and Manipulation	Finger dexterity Manual dexterity Cramped/Awkward workspace
Creative Intelligence	Originality Fine arts
Social Intelligence	Social perceptiveness Negotiation Persuasion Assisting and caring for others

Source: Frey and Osborne (2013)

By constructing these probabilities, Frey and Osborne (2013) provide quantitative estimates of the number occupations that will be highly susceptible to automation over the next two decades. However these estimates do indicate how many actual jobs are at high risk for automation over this time frame.

8.2 Canadian Employment Impact Scenarios

I calculate two scenarios based on Frey and Osborne’s (2013) occupation-level automation probabilities to estimate the proportion of Canadian jobs that are at high-risk for automation over the next two decades. The first is the Maximal Employment Impact

(MEI) scenario. It is calculated by summing the total number of Canadians employed in occupations classified as high risk by Frey and Osborne (2013) in 2013.¹⁶¹⁷ The calculation is repeated with employment projections for 2022 from the Canadian Occupational Projection System (COPS) to assess how expected shifts in the occupational distribution of the workforce impact the 2013 estimates.¹⁸ The MEI scenario assumes the near future emergence of technologies that are capable of fully automating high risk occupations, and that the technologies will be universally adopted by firms. It therefore provides a baseline estimation that can be adjusted to account for other factors.

The second scenario is the Probability-Adjusted Employment Impact (PAEI) scenario, which is risk-weighted version of the MEI scenario. It is calculated by multiplying the number of persons employed in each high-risk occupation by the automation probability assigned to that occupation, and summing the results for all occupations. The same is repeated for employment projections for 2022. The PAEI scenario factors in uncertainty about future technological developments and their adoption by firms into estimates of the number of jobs at high risk of automaton.

Table 3 contains the aggregate results of the two scenarios for 2013 employment data and 2022 employment projections. Under the MEI 2013 scenario, 50% of Canadian jobs are at high risk for automation over the next two decades, while 43.5% are at high risk under the PAEI scenario. Under the MEI 2022 scenario 48.7% of Canadian jobs are at high risk for automation, while under the PAE scenario it is 42.5%.

¹⁶ See Appendix A for details on the procedure.

¹⁷ For occupation-level automation probabilities see Appendix C.

¹⁸ The Canadian Occupational Projection System is run by Employment and Social Development Canada.

Table 3. Percentage of Total Canadian Jobs at High Risk for Automation

	<u>2013</u>		<u>2022</u>	
	MEI	PAEI	MEI	PAEI
High Risk	50%	43.5%	48.7%	42.5%
Non-High-Risk	50%	56.5%	51.3%	57.5%

Two conclusions emerge from these results. First, the magnitude of automation susceptibility does not change substantially when uncertainty is factored into the scenarios. The difference between MEI and PAEI is 6.5% for 2013 data, and 6.2% for 2022 data. This is due in part to the use of high-risk occupations in the scenarios; it also indicates that among occupations that face a high risk of automation, those with the largest employment-share are also amongst the most highly susceptible to automation. Second, projected occupational shifts in the labour force between 2013 and 2022 do not substantially reduce the automation risk. The difference between MEI 2013 and 2022 is just 1.3%, and 1% for PAEI. Therefore, assuming the accuracy of the projections, expected shifts in the occupational distribution of labour do little to mitigate automation risk.

Figures 16 and 17 display the MEI and PAEI scenarios aggregated by NOC occupation grouping. They show the proportion of jobs within each occupation grouping at high risk for automation. The results for 2013 and 2022 employment figures do not substantially differ. Of the ten groupings, four have >50% of jobs at high-risk of automation under both scenarios, indicating potentially substantial job losses in these occupational categories. Two occupational groupings show between 10-50% of jobs at high-risk, indicating moderate potential job losses in these occupational grouping. The final four occupational groupings show <10% of jobs as high-risk, indicating low job losses in these occupational groupings. Table 4 summarizes these results. Overall, the results indicate that susceptibility to automation in the next two decades is very significant in nearly half of all NOC occupational groupings. The pattern of occupational groupings in the High (>50%) versus Low (<10%) categories implies declining shares of total employment in industry, trades, and services, and increasing shares in high-skill research, administration, and artistic/cultural occupations over the next two decades.

Figure 16. Percentage of Jobs at High Risk within NOC Occupation Groupings (2013)

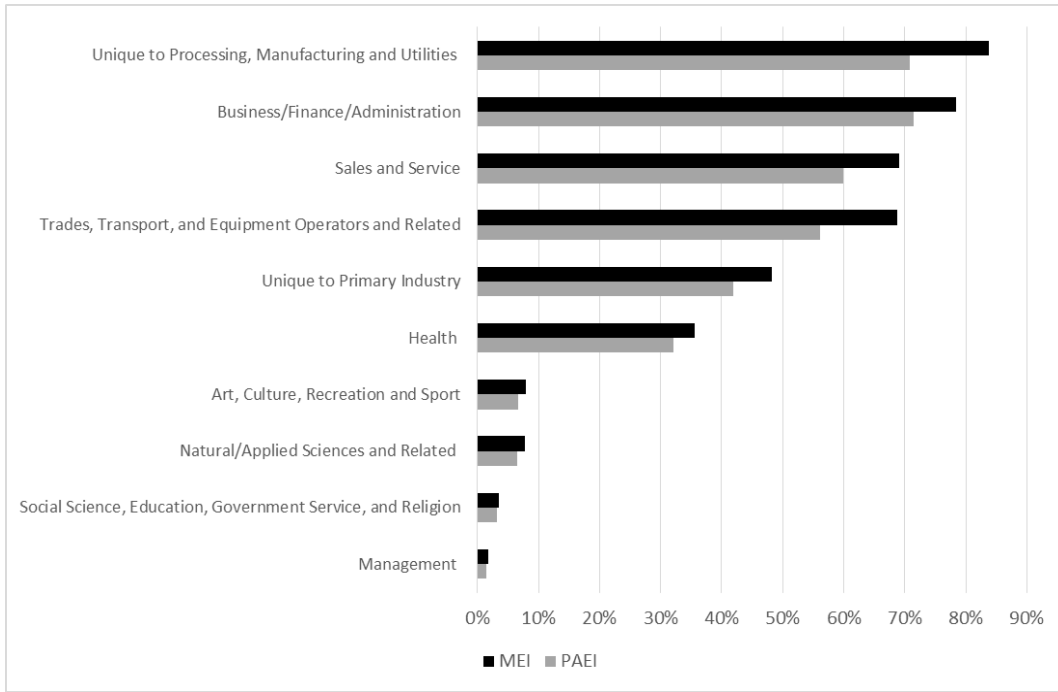


Figure 17. Percentage of Jobs at High Risk within NOC Occupation Groupings (2022)

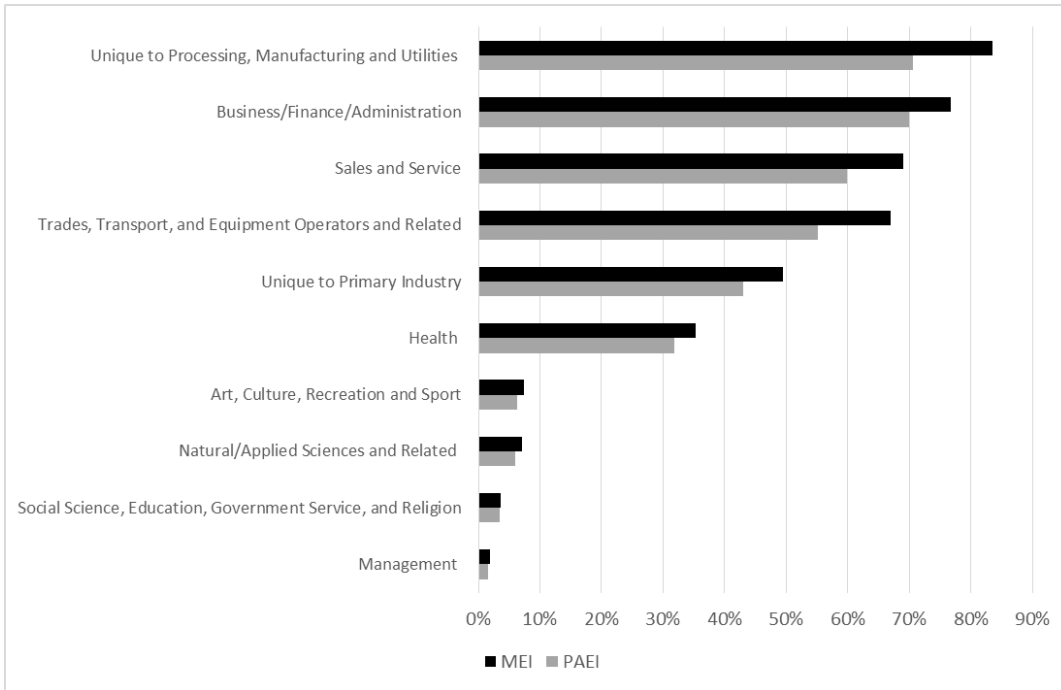


Table 4. Level of Automation-risk by NOC Occupational Grouping

Proportion of Jobs at High-Risk	NOC Occupational Grouping
High (>50%)	Unique to Processing, Manufacturing, Utilities Business, Finance, Administration Sales and Service Trades, Transport, Equipment Operators, and Related
Moderate (>10% - <50%)	Unique to Primary Industry Health
Low (<10%)	Art, Culture, Recreation, and Sports Natural, Applied Sciences, and Related Social Science, Education, Government, Religion Management

Figures 18 and 19 show the share of total Canadian employment by NOC occupation grouping in descending order, and the proportion of this share at high risk for automation under the MEI and PAEI scenarios.¹⁹ The results for 2013 and 2022 employment figures do not substantially differ. The top three occupational groupings currently account for roughly 57% of total employment. Under MEI this proportion drops to 16%, while under PAEI it drops to 21%. Occupations within groupings that are least vulnerable to automation currently make up 36% of total employment. Under MEI and PAEI this proportion drops to approximately 32%. These findings imply first, that very significant job losses in low- and medium-skill occupations that currently employ the majority of the Canadian workforce are possible; and second that the proportion of workers employed in high-skill research administration, and artistic/cultural occupations will need to more than double to prevent significant levels of automation-driven structural unemployment from occurring.²⁰

¹⁹ For specific values by industry see Appendix B.

²⁰ Note that this does not imply that employment within *current* occupations in these NOC groupings must more than double. Rather, that employment shares in occupations (current or new) that require skills found in these groupings must more than double.

Figure 18. Percentage of Canadian Jobs by NOC Occupation Grouping with Proportion at High Risk (2013)

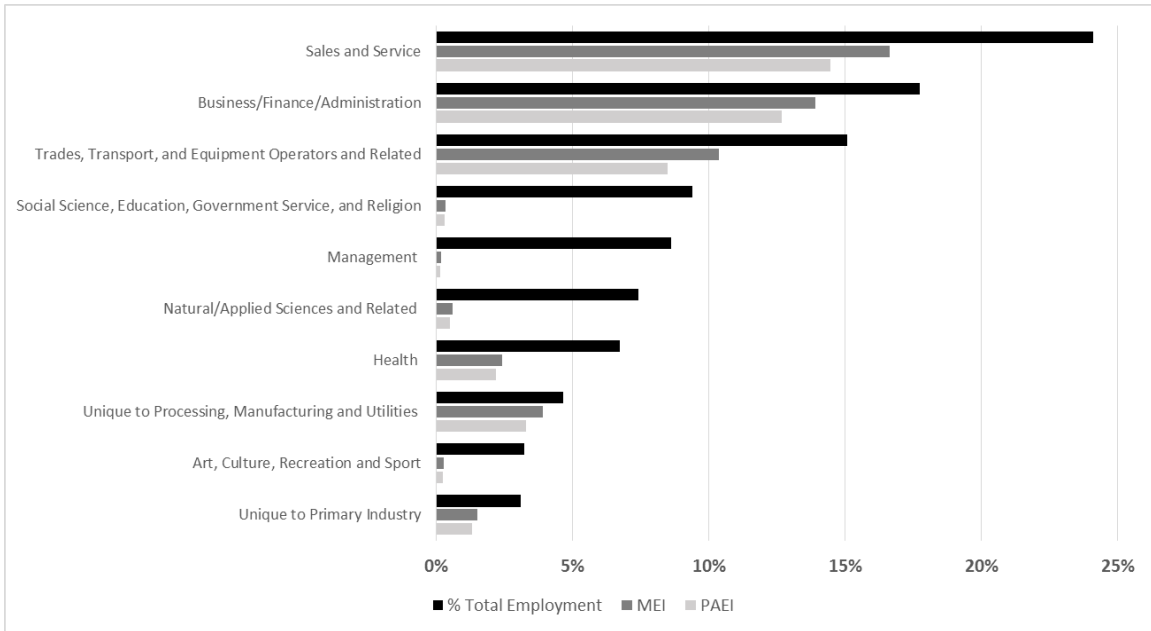
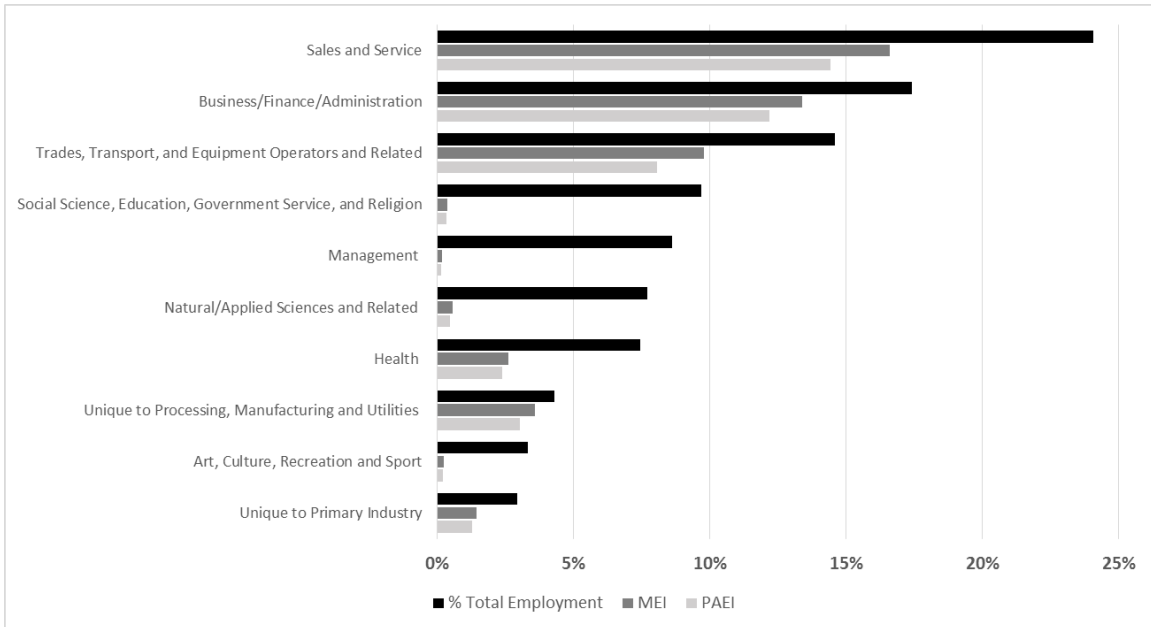


Figure 19. Percentage of Canadian Jobs by NOC Occupation Grouping with Proportion at High Risk (2022)



8.3 Additional Variables

There are factors not taken into consideration here that can influence firms' decision to adopt automation technologies. Firm-size has been hypothesized to have a strong positive relationship with the adoption of new technologies (Hall and Khan, 2003; Swamidass and Kotha, 1997). Studies in the banking sector and manufacturing provide empirical support for these arguments (Saloner and Shepard, 1995; Baldwin and Diverty, 1995). Thus, the rate and magnitude of job automation will likely be impacted by the distribution of firm sizes in industries.

Consumer preferences are will also have an impact. If consumers prefer dealing with human agents then firms in competitive markets may have an incentive not to adopt automation technologies. Meuter, et al. (2000) finds frequent customer complaints concerning malfunctioning technology, process failures, poor design, and over-reliance on customer competency in transactions as reasons for preferring human agents over a variety of self-service machines. Lack of trust and lack of familiarity with automation technologies are also common reasons for preferring human agents (Dabholkar and Eun-Ju Lee, 2003). Reinders, et al. (2008) finds significant negative reactions by consumers who were forced to use entirely technology-based self-services without alternatives. These findings indicate that consumer preferences could impact the uptake of automation technologies by firms.

Based on these findings it is likely that the estimates for job losses in both the MEI and PAEI scenarios will fall when additional variables are factored in. Nevertheless, these scenarios are useful for approximating the magnitude of the vulnerability of Canadian jobs to automation in the near future.

The results discussed in this section indicate that automation-driven job losses in coming decades could be substantial. In previous decades automation reduced employment in a limited set of industries (see Chapter 3). Current and developing automation technologies have the potential to reduce employment in several industries that collectively employ the majority of the Canadian labour force. Although some industries are unlikely to be affected by automation the near-term, these industries are also unlikely to generate enough labour demand to offset declines elsewhere.

Occupations in Art, Culture, Recreation, and Sports, and Social Science, Education, Government, and Religion, do not historically generate a significant proportion of aggregate labour demand. Occupations in Natural and Applied Sciences tend to drive demand for high skill labour only, leaving low- and medium-skill workers with few employment options. In the remaining part of my study I derive and assess a set of policy options to mitigate the adverse impacts of spreading automation and help employment adjustment.

9. Policy Objective, Criteria, and Measures

In this section I set out the policy objectives and briefly define the criteria and measures that are used to assess the policy options.

9.1 Policy Objective

Over the next two decades automation technologies will likely substitute for labour in an increasingly large proportion of current occupations. The policy objective is therefore to minimize automation-driven structural unemployment by facilitating the reallocation of labour to occupations that remain in-demand.²¹ Quantifying structural unemployment due to automation faces two difficulties however: first, reliably measuring structural unemployment requires high quality data on job vacancies that is not currently available (Riddell, 2000; Drummond, et al, 2009); and second, data that provides direct visibility on the specific contribution of automation to unemployment is not currently collected in Canada. As a proxy measure, I use the average of 8% and range of 6-12% of Canadian annual unemployment rates between 1980 and 2013 as reference values (OECD, 2014b). This period contains several recession and expansion periods and so factors in variation due to cyclical and frictional unemployment. Due to the ongoing development of automation technologies I assume that some increase in unemployment above the 1980-2013 average of 8% is likely unavoidable over the next two decades, but that unemployment rates above the maximum value of 12% are potentially avoidable. Therefore, the policy objective is to maintain the unemployment rate between 9% and

²¹ Although there are other policy objectives that theoretically address the policy problem, they are assumed to be infeasible and/or undesirable given the current institutional and cultural context; examples include the suppression of automation technologies, or regulations governing their implementation in the private sector.

12%.²² Sustained increases beyond 12% indicate the presence of significant automation-driven structural unemployment.

Table 5. Policy Objective

Timeframe	Objective	Measure
20 Years	Minimize automation-driven structural unemployment through the reallocation of labour to occupations that remain in demand	Unemployment rate between 9-12%

9.2 Evaluation Criteria and Measures

A set of criteria is used to rank the policy options; they are: equity, effectiveness, cost, administrative complexity, and stakeholder acceptability. For some criteria, policy options are assigned a score of either high, medium, or low. High scores received 3 points, medium 2 point, and low 1 point. Other criteria are assigned a score of either high or low, with high receiving 3 points and low receiving 1 point. The best policy is determined by summing points and selecting the highest scoring option. No additional weights are assigned to individual criteria. Criteria and measures are summarized in Table 7.

Equity evaluates if a policy takes into account the disproportionate impact of automation on various groups in the labour force. Frey and Osborne (2013) provide evidence that low-skill occupations are among the most susceptible to automation. Groups such as First Nations, Metis, Inuit, and certain visible minority groups that are over-represented in low-skill occupations (ESDC, 2006) will thus be disproportionately impacted by automation in the near-term. Furthermore, because these groups have lower-than-average levels of educational attainment (ESDC, 2006), a larger proportion of these populations will have to make use of programs designed to transition workers to occupations that are less susceptible to automation. The measure for this criterion is whether a policy includes mechanisms to ensure that disproportionately impacted groups benefit from the policy to the same degree as other groups do. If there is no

²² Unemployment could go above the 12% threshold used here for other reasons, e.g. an economic depression – however it is assumed here that these extreme scenarios will not occur in the near future.

benefit the score is low (1); if benefits are equal to other groups the score is medium (2); if benefits are higher the score is high (3).

Effectiveness evaluates how well the policy option meets the policy objective. The measure for this criterion is the unemployment rate over the next two decades based on the 8% to 12% range described above.

Cost concerns the monetary cost of the policy in relation to current federal spending on unemployment mitigation. As a reference value I use total spending by Employment and Social Development Canada (ESDC) on skills-training and education of approximately \$3.5 billion (Bertrand, 2013). This value is the sum of expenditures on federal programs for disadvantaged groups (\$750 million), and transfers to provinces and territories for training and education programs under the Labour Market Agreements and Labour Market Development Agreements (\$2.7 billion). Because the analysis in Chapter 8 implies that a large proportion of total Canadian jobs could be lost to automation, future spending increases to mitigate unemployment are likely unavoidable. Therefore, the measure for this criterion is the percentage increase in expenditures required by the policy above current expenditures. Increases above 65% score low (1); increases between 35% and 65% score medium (2); increases below 35% score high (3).

Administrative complexity evaluates the degree of institutional change that a policy option entails. The creation of new institutions often requires considerable deliberation between relevant parties over funding, mandate, composition, and related issues. Therefore, policy options that require the creation of new institutions are considerably more complex to implement than policies that can be implemented through existing institutions. If a policy can be implemented through existing institutions the score is high (3); if the policy requires the creation of new institutions or significant changes to existing institutions the score is low (1).

Only major stakeholders are considered for the Stakeholder Acceptability criterion. The first component of the criterion is labour force acceptability. Because the policy objective concerns unemployment levels, the labour force is the primary target of the policy options considered. Therefore, labour force opposition will significantly impact policy feasibility. The measure used to estimate labour force opposition is whether or not the policy imposes (potentially or actually) direct costs on labour force participants.

Policies that require the labour force to bear direct costs are assumed to create significant opposition and score low (1); policies that do not have this requirement score high (3). The second component is government acceptability. Because government action is required to address the policy problem, government opposition also impacts policy feasibility. The measure used to estimate this component is the degree of intergovernmental cooperation required. Although cooperation between the federal and provincial/territorial governments is common, these collaborations can involve conflict over constitutional jurisdiction and funding responsibilities. Therefore policies not requiring intergovernmental cooperation are usually preferred. If cooperation is required the score is low (1); if cooperation is required the score is high (3).

Table 6. Criteria and Measures Summary

Criterion	Definition	Measure	Score
Equity	The degree to which the policy assists groups that are disproportionately impacted by the policy problem	Presence of robust policy measures to promote equal policy benefits for disproportionately impacted groups	Disproportionately impacted groups not supported Disproportionately impacted groups receive equal amount of support as rest of labour force Disproportionately impacted groups receive higher levels of support
Effectiveness	The degree to which the policy meets the policy objective	Unemployment rate over the next 20 years	Unemployment >12% Unemployment between 9-12% Unemployment < 9%
Cost	Costs in dollars of implementing and maintaining policy	Total cost in dollars of policy compared to current ESDC spending on unemployment mitigation programs	Spending increases >65% required Spending increases of 35-65% required Spending increases of <35% required
Administrative Complexity	Amount of institutional change required	Creation of new institutions required or significant change to existing institutions	Policy requires the creation of new institutions Policy does not require the creation of new institutions
Stakeholder Acceptability	Opposition to the policy from the labour force Opposition to the policy from governments	Direct costs to members of labour force Intergovernmental coordination required	Labour force participants may be subject to direct costs as a result of policy Labour force participants are not subject to direct costs due to policy Intergovernmental cooperation necessary for implementation of policy Intergovernmental cooperation not required for implementation of policy

10. Policy Analysis

In this section I first outline a necessary condition for implementing policies that address the policy problem; second I describe and evaluate three policy options with respect to the criteria set out in Chapter 9; third, I provide policy recommendations based on the foregoing analysis.

10.1 The Need for Labour Market Information

Due to the uncertainty regarding the scope and pace of future labour automation, detailed, up-to-date labour market information is critical. To provide this information a Labour Market Information Systems (LMI) is needed. LMIs perform two roles: First, they increase the efficiency of labour market adjustments by lowering the transaction costs for both job-seekers and employers of finding suitable job-matches. Increased efficiency helps reduce the negative externalities associated with inefficient job-matching, such as high workplace turnover and potentially higher costs for social support programs (Sharpe and Qiao, 2006). And second, they provide timely, accurate information to policy-makers.

Despite the volume of data collected at all levels of government and in the private sector, recent analyses have found significant gaps in Canada's LMI. The Advisory Panel on Labour Market Information (Drummond, et al. 2009) finds significant data gaps concerning education, compensation, job vacancies, workforce characteristics, regional labour markets, labour mobility, vulnerable groups, skill supply and demand, and projection data. Issues with timeliness of data, awareness of the availability of data, access to data, and availability of relevant analysis and interpretation of data are also found.

A comprehensive and reliable Canadian LMI is a prerequisite to effectively addressing the problem of automation-driven structural unemployment. Without this

information policies cannot be effectively designed or evaluated. Therefore, the policy analysis below assumes that the recommendations of the Advisory Panel on Labour Market Information (Drummond, et al. 2009) will be fully implemented.

10.2 Option 1: National Skills-Training Framework

As the pace and scope of automation increases, increasing numbers of workers will require training in order to qualify for jobs in occupations that have not been automated. There is growing recognition in Canada of the importance of on-going skills-training and development in the labour force to meet changing patterns of labour demand (Cappon, 2014). Canada currently has a wide range of skill-training and development programs offered by multiple providers. At the federal level, Employment and Social Development Canada (ESDC) delivers programs that target specific vulnerable groups such as First Nations and those with disabilities. Under the Labour Market Agreements (LMI) and Labour Market Development Agreements (LMDI), general skills-training program delivery has been largely devolved to the provinces and territories. Training is also coordinated through the publically funded non-profit Sector Council Program, a national industry-led coalition of 33 councils that offers targeted training programs and skills development tools to facilitate better matching between industry needs and worker skillsets (Verma, 2012).

Significant deficiencies in the current system have been identified. Halliwell (2013) finds that while Canada's 'first chance' education system (primary and secondary school) functions well, it's 'second chance' system of adult education and skills training tends to benefit those who are already highly skilled. Cappon (2014) compares the Canadian education and skill-training outcomes with those in other developed countries and finds that Canada underperforms on a number of measures. Much of the problem is attributed to the fact that Canada does not have an over-arching intergovernmental education and skill-development framework like those in many other developed nations. These frameworks provide system-wide goals and objectives, clear funding rationale, quality assurance mechanisms, and mechanisms for facilitating intergovernmental collaboration (Cappon, 2014). Australia, which is constitutionally similar to Canada, leaves education provision to sub-national governments, but also has a federal

Department of Education that collaborates with the sub-national governments to establish national programs. Similar arrangements exist in Germany and Switzerland (Cappon, 2014).

This policy option proposes to create of a federal-provincial-territorial Council of Ministers led by the federal government to establish and administer a national framework for training and learning. This framework would set broad objectives, funding priorities, and performance targets, and provide mechanisms for measuring outcomes. It would also provide a means for coordinating government programs such as Employment Insurance (EI) to ensure adequate supports for those participating in training programs.²³ In doing so, the policy option aims to ensure that skills-training programs nation-wide are equipping labour force participants with skills needed to enter occupations that are less susceptible to automation.

Equity

The policy option does include measures to address the needs of groups that will be disproportionately impacted by the automation of low-skill labour in the near term. However, a policy option should not be assigned a high score for this criterion simply because it includes programs designed to address the impact of automation on disadvantaged groups. Many skills-training and development policies are designed to assist low-education or low-income groups, but researchers consistently find that these programs instead disproportionately benefit high-skill workers (Halliwell, 2013). To avoid this outcome, the policy includes the setting of national targets, funding arrangements that promote alignment with these targets, quality assurance mechanisms to monitor outcomes, and mechanisms to facilitate access to financial supports such as EI to assist those who otherwise could not afford to attend long-term training. Due to the inclusion of these mechanisms to ensure that disproportionately impacted groups receive heightened levels of assistance, the policy option is assigned a score of high (3) for this criterion.

²³ Access to income assistance, including EI and other programs, is, and will become, increasingly important as an increasing number of workers take part in skills training programs. This is an important policy issue in its own right, but is beyond the scope of the current analysis. For an overview of current issues in this area and recommendations for reform see Bramwell (2011).

Effectiveness

Empirical evidence regarding the outcome of government-supplied skills-training for adults is mixed, and serious methodological concerns about program evaluations have been raised (Hum and Simpson, 2002). However the research does suggest that publically-funded skill development programs can have a significant impact on employment when properly administered through a national oversight body. Sweden's National Labour Market Board (AMS) oversees free training courses to all adult workers who are either unemployed or facing layoffs, with programs specifically focused on low-skilled workers and workers whose occupations face declining demand (OTA, 1986). The programs last for one year on average. In the 1980s roughly 1% of Sweden's labour force participated in these programs annually, with three-quarters of participants finding a job in their field of study within six months of graduation (OTA, 1986). Assuming similar rates of success under a National Skills Training Framework in Canada, an automation-driven cumulative participation rate of 20% of the Canadian labour force over the next two decades implies a 5% increase in unemployment.²⁴ With current unemployment in Canada at 6.5%, this increase implies an unemployment rate of 11.5% under this policy. The policy is therefore assigned a score of medium (2) for this criterion.

Cost

Current federal spending and transfers under the LMAs/LMDAs and Canada Job Grant is roughly \$3.5 billion. The policy option proposes to augment the current system with a national skills-training framework administered by a Council of Ministers (Cappon, 2014). The role of this council would be to set the strategic direction, priorities, and conduct evaluations, but not create or administer programs. The costs associated with these tasks would fall well below the 35% (or \$1.2 billion) minimum threshold. However a cost assessment of the policy must take into account increases to LMA/LMDI transfers as participation rates in skills-training programs rise as a result of increasing automation-driven job losses. Under the Canada Job Grant the maximum federal funding for

²⁴ A 20% participation rate was chosen as this is roughly 50% of the total number of jobs at high risk automation under the PAEI scenario. This value attempts to take into account factors that could affect the number of jobs lost to automation discussed in section 8.3 above.

individuals is \$15,000. Using this value as a baseline, the cost for re-training all persons whose jobs are at high-risk of automation in the near future is roughly \$114 billion. This amounts to \$5.7 billion per year over the next two decades, a 153% increase in federal spending on unemployment mitigation-related spending and transfers.²⁵ More realistically, if it is assumed that approximately 50% of workers whose jobs are lost to automation participate in skills-training programs, this spending increases between 82% are still implied, well above the 65% threshold on this measure.²⁶ The policy therefore receives a score of low (1) for this criteria.

Administrative Complexity

A central component of the policy option is the creation of a new institution: a joint federal-provincial-territorial Council of Ministers. Although superficially similar, the current Council of Education Ministers, Canada (CMEC), this body does not include representatives from the federal government and does not create or enforce binding agreements. Therefore, although CMEC could be used as the basis of a new council, its mandate and structure would require significant modification. This task faces the same challenges as the creation of a new institution, such as the determination of mandate, funding responsibilities, structure, and composition. Because the policy option entails the creation of new institution, it is assigned a score of low (1) for this criterion.

Stakeholder Acceptability

Current skill-training programs at both the federal and provincial-territorial levels do not require participants to pay up-front fees or require repayment of training costs at a later date. However, because significantly more workers would be participating in education and skills-training programs under the policy option, increased government revenues will likely be required to cover the costs. The labour force need not be the source of this additional revenue however. Increases in corporate tax rates in proportion to capital income shares, for example, would allow governments to pass part of the cost

²⁵ The number of workers used in this calculation comes from the 2013 PAEI scenario.

²⁶ Additional costs are likely with increased EI claims. Estimates of the total cost of EI claims for participants in training programs have not been made as only the direct costs of the policy option are considered here. For a breakdown of actual and projected EI program costs for the period 2012-2014 see Office of the Chief Actuary (2013).

of re-training onto firms who have chosen to automate their production processes. Because the policy option does not require direct costs to be imposed on the labour force, it is assigned a score of high (3) on this measure.

Government opposition to the policy by the federal and provincial/territorial governments is likely to be high. Although the provinces have constitutional authority over education policy, the federal government played an active role in skills-training programs up until 1995. However, in 1995 the federal government devolved most of these responsibilities to the provinces and territories through the LMIs/LMDIs. By proposing to reintroduce federal leadership through a national skills-training framework, the policy entails significantly greater intergovernmental cooperation on education and skill-training than has been the case over the last twenty years. The policy is assigned a score of low (1) on this measure.

10.3 Option 2: Incentivize Private Sector Skills-Training Activity

Firms in Canada provide roughly 33% of job-related courses and cover 63% of the costs for training courses (OECD, 2006), highlighting the significant role that employer-led training plays in workforce skills development. However, annual per-employee spending on training in the Canadian private sector has fallen by 40% since 1993 (Cappon, 2014). As an increasing numbers of jobs are lost to automation the demand for skills-training will only accelerate as workers attempt to transition to occupations that do not face automation.

In 2013 the federal government of Canada shifted to a policy of greater employer involvement in skills-training with the Canada Job Grant. Under this program the federal government will supply cash grants of up to \$15,000 for employer-sponsored training, with equal amounts being contributed by provincial governments and employers. Financing for the grants will be provided by cutting federal transfers to the provinces under the LMIs by \$300 million (Mendelson and Zon, 2013). Similar subsidization policies for employer training exist in France where public shares of funding can be as high as 70%, and in Ireland through the Training Support Scheme that provides subsidies for training that is explicitly linked to business strategies (Stone, 2010).

This policy option proposes to provide employers with an array of incentives to hire and provide training for workers whose skills have been made obsolete by automation. This would facilitate a reallocation of labour to occupations that are less susceptible to automation, and so potentially mitigate some of the structural unemployment that would otherwise occur. Possible instruments to incentivize employer-led training include cost-reimbursement, cost-redistribution, levy-exemption, and tax credits (Johanson, 2008).

Equity

The policy option proposes to incentivize firms to provide more training to employees through the use of instruments such as tax credits, training funds, and greater support for sector councils. Incentivizing firms to invest in employee training will almost certainly benefit employed workers more than the unemployed who are more likely to be members of disproportionately impacted groups. It could be argued that the policy instruments above could be used to incentivize hiring of disadvantaged persons. However, as automation spreads it is also likely that larger numbers of skilled workers will be displaced, providing employers who have not automated with the opportunity of hiring already-skilled workers. Members of disproportionately impacted groups will likely receive little benefit from the policy. It is therefore assigned a score of low (1) for this criterion.

Effectiveness

The effectiveness of the policy depends on the willingness of employers to provide training, which in part depends on the resources firms have at their disposal. The policy option assumes that the resource constraints that firms face with respect to employee training relate only to immediate training costs. However firms also face administrative and human resource constraints that can make formal training infeasible (Mendelson and Zon, 2013). Consistent with this claim, research indicates that SMEs generally only provide informal training opportunities for employees (Canadian Chamber of Commerce, 2013). Informal on-the-job training, however, will not prepare most workers for high-skill occupations that they do not already possess a complementary skill-set for. High skill competencies often require years, not weeks or months, of study to acquire, and so are infeasible for even large employers to offer. Unless the training is of short duration and candidates possess a complementary skills-set, firms are unlikely

to provide it. Greehalgh's (2001) find evidence for this problem in France's use of training levies. While French firms did provide more employee-training than British firms who were not subject to a levy, already high-skilled workers were the main beneficiaries. The infeasibility of offering intensive formal training could also have the perverse side-effect of incentivizing firms to look for ways to automate or outsource processes if no qualified personnel are available. Hiring rates would therefore almost certainly be insufficient to prevent unemployment from exceeding 12% as automation technologies spread. For these reasons the policy is assigned a score of low (1) for this measure.

Cost

The cost of implementing the policy option is difficult to assess, as the base level of funding could vary based on a number of factors. As a reference point, the Canada Job Grant costs \$600 million, or 17%, of a total of \$3.5 billion in skills-training expenditures and transfers per year. These costs will rise as the number of workers being trained in the private sector increases, and so additional government revenues will be required. Assuming that firms hire and train approximately 50% of workers whose jobs are lost to automation in the PAEI scenario, and federal costs remain at \$15,000 per worker, then federal expenditures will rise from \$600 million per year to \$2.9 billion. This constitutes an increase of \$2.3 billion or 61% of current total expenditures. This 50% estimate is likely very high however given falling labour demand, implying costs well below 65% of current expenditures. Expenditure increases below 35% are unlikely given increasing demand for high-skill workers in the near-term and incentives for firms to cover their training costs with public funds. Therefore spending increases between 35-65% are most plausible, and the policy is assigned a score of medium (2) for this criterion.

Administrative Complexity

The instruments that are included in the policy option are modifications or extensions of existing instruments. Training subsidies, for example, are currently offered through programs like the Canada Job Grant administered by ESDC, while tax incentives such as the Apprenticeship Job Creation Tax Credit are administered by the Canada Revenue Agency. Although the number of firms utilizing these options is likely to increase under the policy option, it is unlikely that new institutional arrangements

would be required to manage this change. The policy is therefore assigned a score of (3) for this criterion.

Stakeholder Acceptability

Under this policy option the direct costs for training are partially covered by government subsidies to firms, and partially covered by the firms themselves. Workers, however, face at least two additional sources of direct costs. First, high-skill jobs in Canada are increasingly concentrated in urban centres (Alasia and Magnusson, 2005). If this trend continues, workers in non-urban areas will increasingly be required to relocate to urban areas to take advantage of skills-training, thus incurring the costs associated with such a move. Second, most firms who offer employee training have clawback policies to recover costs if employees leave within a set post-training period. Training subsidies will not likely change this practice, as training costs are only one component of total hiring costs. Although workers can avoid incurring these costs in most cases, the potential for incurring them in order to receive training will likely result in labour force opposition to the policy. Therefore, the policy is assigned a score of low (1) on this measure of the criterion.

Under this policy, the federal government acts as a funding agency while the provision of training is left to private sector organizations. Because demand for training is driven by the decision of firms to hire and train new workers, no performance targets or national priorities are built into the policy. This appears to minimize the need for intergovernmental cooperation. However because the responsibility for education and training policy was largely devolved to the provinces and territories as part of the LMIs/LMDIs it is unlikely that they would be willing to cede any control back to the federal government. The possibility of conflict is even stronger if funding for the policy requires cuts to provincial transfers such as those under the Canada Job Grant. Although the policy could in principle be implemented by the federal government unilaterally, in practice intergovernmental coordination will almost certainly be required. The policy is therefore assigned a score of low (1) on this measure of the criterion.

10.4 Option 3: Public Support for the Creation and Development of SMEs

Empirical studies show a strong positive correlation between firm size and the adoption of new technologies (see section 8.3). Just over 50% of the Canadian work force is employed in large firms, one of the highest proportions in the OECD (Canadian Council, 2009; OECD, 2012).²⁷ Since 2001, however, small and medium sized enterprises (SME) have accounted for 43% of employment growth (Industry Canada, 2012). Although the competitive advantages of large firms in terms of human and capital resources have long been recognized, small firms also play an important role in economic development (Edmiston, 2007). This suggests that increased government support for the creation and development of viable SMEs could help offset declining labour demand in large firms due to the adoption of automation technologies. In the context of spreading automation, such a policy would be unlikely to harm large firms, as most of the labour drawn into SMEs would be otherwise unemployed.

At the federal level, the Canada Small Business Financing (CSBF) program currently provides partial guarantees on private small business loans of up to \$500 000 for financing property acquisition, leasehold improvements, or equipment purchases. SMEs can also secure loans, private-sector line of credit guarantees, and other financial services for all stages of the business lifecycle from the Business Development Bank of Canada (BDC). The intergovernmental Community Futures Program performs a similar role for agricultural businesses. A number of loan guarantee, grant, and business training programs are also offered at the provincial and territorial levels; however these programs tend to target specific types of businesses, and generally offer smaller loan guarantees.

Of the providers listed above, the BDC has the most expertise and offers the widest variety of financial and consultation services related to SME creation and development. It also has an existing physical presence in every region. The policy option proposes to consolidate federal SME-support activities under the BDC and expand program activity in order to increase the number of viable SMEs in Canada.

²⁷ Large firms are defined as those having more than 250 employees

Supporting their development could generate labour demand to offset declining labour demand in large firms, and so reduce automation-driven structural unemployment.

Equity

The CDB currently offers support programs targeting members of disadvantaged groups, such as the Aboriginal Business Development Fund which offers both loans and management training. Similar programs could be designed and offered to other disproportionately impacted groups as well. Therefore, it appears that these groups do have access to additional financial and knowledge supports under this policy. It should be questioned, however, if in the context SME development the provision of targeted financing and consultation programs alone does constitute 'additional assistance'. The ability to successfully start and manage a business has been strongly linked to educational attainment (Gimeno, et al. 1997). Consistent with this research, 63% of Canadian small business owners in 2007 had completed some level of post-secondary education (Fisher, et al., 2010). Many of the people who will be most impacted by automation, however, come from backgrounds or environments that present challenges to educational attainment. Therefore, the provision of targeted SME support programs is unlikely to provide equitable benefits due to skill-based barriers to entry. Because targeted SME-support programs have unintentional barriers to entry for members of these groups, it cannot be assigned a score of medium (2) for this criterion.

Effectiveness

Between 2001 and 2011 Canadian small businesses created 559,484 jobs, which translates to an average annual increase of 56,000. The potential total number of jobs lost to automation over the next two decades under the PAEI scenario implies to an annual average loss of 381,000 jobs. To offset these losses, average annual SME job creation would need to increase by 580% under the policy. Doubts about the plausibility of meeting this target are raised by a recent assessment of the CSBF program that finds no link between public SME support policies and employment growth (Song, 2014).²⁸ If,

²⁸ Song (2014) notes however that the apparent lack of employment growth attributable to the CSBF program could also be due to large job losses in the recession of 2008-2009, likely obscuring any positive employment effects of the program.

only slightly more realistically, the policy results in average annual SME job creation of half this amount (or 290%), an unemployment rate between 15-25% would still result. The policy option is therefore unlikely to keep the unemployment rate below 12% and so is assigned a score of low (1) for this criterion.

Cost

The two largest sources of publically-funded financial and consulting support services for Canadian SMEs are the BDC, and the CSBF program. In 2014 the BDC provided loans totaling roughly \$4.1 billion to 9,529 Canadian SMEs (BDC, 2014), while the CSBF program averaged 8,509 loans guarantees annually with a total annual value of approximately \$988 million between 2004 and 2013 (Industry Canada, 2014). Under the policy, all federal SME support programs would be consolidated under the BDC, implying that under current conditions the BDC would handle 18,000 loans worth \$5 billion annually. As automation-driven unemployment increases, the total value of SME loans can be expected to rise over time as well. A 50% increase in loan activity would translate to 27,000 loans worth \$7.6 billion annually, which represents a 73% increase in spending compared to current annual federal spending on unemployment mitigation programs. Thus, even without taking into account higher administrative costs from increased SME creation and development, the policy is likely to require spending increases greater than 65% threshold, and so is assigned a score of low (1) for this criterion.

Administrative Complexity

The advantages of consolidating federal SME support services under the BDC stem from BDC's existing areas of expertise and physical presence in all provinces and territories. Because an expanded role in administering SME support programs is fully consistent with the BDCs current activities and mandate, no significant modifications to its institutional makeup are required by the policy.²⁹ Neither does the elimination of the CSBF and various small federal small business programs as separate programs require changes to other federal organizations. Although several provinces/territories do have

²⁹ See section 4 of the Business Development Bank of Canada Act (S.C. 1995, c. 28) for wording of the BDCs mandate.

targeted SME support policies, the policy option does not impact the way these programs are funded and administered. Therefore it is unlikely that the policy would require significant change to existing institutional arrangements at any level of government, and so is assigned a score of high (3) for this criterion.

Stakeholder Acceptability

Workers or small business owners who participate in SME support programs under the policy will potentially incur costs if they are unable to repay their loans. These debts can be substantial. In 2014 the average loan provided by the CDB was \$430,000. Although much smaller loans are available, this figure highlights that participation in policy-related programs entails temporary indebtedness, with the potential for long-term indebtedness as well. There are also potential earnings costs to increasing employment in SMEs. Industry Canada (2014) finds that on average, workers in small enterprises earn 19% less than workers in large firms, while workers in medium firms earn 12% less. Therefore even if the policy successfully increasing the proportion of Canadians employed in SMEs, workers would likely face a reduction in earnings. Because the policy does entail direct costs for members of the labour force, it is assigned a score of low (1) on this measure of the criterion.

The BDC currently operates in every province and territory offering many, if not identical, services to SMEs that would be offered in an expanded form under the policy. These activities fall within the federal government's constitutional jurisdiction and so do not require intergovernmental cooperation. The policy is therefore assigned a score of high (3) on this measure.

Table 7. Policy Option Evaluation Summary

Criterion	Skills Training Framework	Private Sector Training	Public SME Assistance
Equity	3	1	2
Effectiveness	2	1	1
Cost	1	2	1
Administrative Complexity	1	3	3
Labour Acceptability	3	1	1
Government Acceptability	1	1	3
Total	11	9	11

10.5 Policy Recommendations

Two results emerge from the policy options. First, policy option 2 is inadequate, due largely to undesirable equity impacts and low effectiveness.³⁰ Second, although options 1 and 3 receive the same total score, they have different strengths and weaknesses. Option 1 receives the highest scores on equity and effectiveness, but scores low on administrative complexity. Option 3 is less equitable and less effective, but scores high on administrative complexity. The options receive the same score on Stakeholder Acceptability, but also for different reasons. Option 1 scores high on labour force opposition, but low on government opposition; option 2 scores low on labour force opposition, but high on government opposition. Therefore, the strengths of options 1 and 3 are the other's weaknesses, and vice versa.

³⁰ Although the total score of option 2 is close to the totals of the other options, this does not mean that option 2 is nearly as desirable a policy as the other options. Total scores provide only an ordinal ranking of options. Therefore, the fact that policy 2 is only two points lower than the other options does not give any indication of how much less preferable option 2 is. To determine this, a more detailed analysis of the relative importance of each criteria to impose weights is required; however this is beyond the scope of the current analysis, and does not impact the policy recommendations.

These scores, along with the fact that option 1 is labour supply focused while option 3 is labour demand focused, suggest complementarities between the policies. Equity issues with option 3 could be mitigated by option 1, as skill-training policies could provide individuals with low levels of education the ability to more effectively utilize SME support programs. Conversely, increasing support for viable SMEs through option 3 could increase demand for workers who are unable to transition to high-skill occupations through skills-training programs. By targeting both labour supply and demand aspects of the policy problem, the combination of options 1 and 3 would be more effective at reducing unemployment and promoting equity than either policy individually. In addition, a combination of these policies would be no more administratively complex, nor face greater opposition than each of the policies individually.

Cost is the largest barrier to implementing options 1 and 3 together, as both options score low on this criterion. The changing nature of automation-driven structural unemployment over the next two decades indicates the possibility of a less costly phased approach however. In the near term, demand for high-skill labour will likely remain strong due to technological barriers preventing automation (see section 8.1). This suggests an emphasis on option 1 to promote the alignment of labour supply characteristics with changing labour demand requirements. As technological barriers are overcome, however, the source of automation-driven structural unemployment will shift from a mismatch between labour supply characteristics and labour demand requirements, to a lack of aggregate labour demand across the skill distribution. This suggests the need to stimulate labour demand by transitioning the policy emphasis to option 3.³¹ By shifting resources from option 1 to option 3 as the dynamics of automation-driven structural unemployment change, policy complementarities can be exploited while spreading costs over time.

The policy challenge of increasing automation-driven structural unemployment over the next two decades requires addressing changes in both the composition and magnitude of labour demand. A flexible policy response that targets labour demand and labour supply is therefore required. Combining a national skills-training framework with

³¹ Note that this does not imply switching completely from one option to the other. Both policies should be implemented simultaneously, but the amount of resources devoted to each policy should vary depending on what the main cause of structural unemployment is at a given time.

strengthened policies to support the creation and development of Canadian SMEs meets this requirement.

11. Long-Term Considerations

Beyond the next two decades, automation technologies may develop to a point where they are widely substitutable for human labour across the skill distribution. Human labour will persist wherever automation is prohibitively expensive, or consumer preferences for human input are strong. However labour supply will likely greatly exceed demand. The result will be very high structural unemployment. If policies cannot significantly alter the rate of structural unemployment, then the focus must shift from mitigating unemployment to maintaining living standards. Policy options for achieving this objective will need to consider mechanisms for income and wealth redistribution. It is beyond the scope of this paper to examine potential options in detail. However I briefly describe one of the options that is often raised in this context.

Universal Basic Income (UBI) is a method of income redistribution that provides individuals with a publically-funded income that is not conditioned on factors such as employment status or current income (Clark and Kavanagh, 1996). Distribution can take many forms including stakeholder or capital grants, negative income taxes, or direct cash transfers (De Wispelaere and Stirton, 2004). No full UBI system has ever been instituted at a national level, but limited forms currently exist. The state of Alaska maintains the Alaska Permanent Fund which invests revenues from natural resource extraction. An annual lump sum payment is made from to each resident of the state depending on the performance of the fund, with values fluctuating between \$1000 and \$3269 per person in recent years (Pasma, 2014). Pilot programs for full UBI have been implemented in India, Brazil, and Namibia (Pasma, 2014). In Canada, randomly selected low-income residents of Winnipeg and all low-income residents of Dauphin Manitoba were given unconditional cash transfers between 1974 and 1979 as part of the 'Mincome' program studying the effects of cash transfers on employment and health (Pasma, 2014).

Although UBI provides a basic standard of living, for cost reasons it would have to fall well below the current median income in Canada of roughly \$53,000.³² Even an annual income of only \$10,000 for every person aged 20 or over would cost roughly \$280 billion per year, doubling the current federal budget. Funding could occur through the elimination of redundant government programs (e.g. EI, income assistance), and through tax reforms that simplify and broaden the tax base (Garfinkel, et al., 2003). In the context of widespread automation, taxation based on capital shares of income could also be considered. However the viability of funding expenditures of this magnitude requires a detailed study of tax policy options, including consideration of potential investment and consumption effects due to high tax rates. Under any fiscally sustainable version of UBI, individuals would also still need to supplement their benefits with other sources of income. However in the context of high levels of automation it is not clear that enough jobs will be available to provide alternative sources of income.

A common claim in favour of UBI is its positive equity impact. Many arguments are made for this claim, but they all relate to the universality of the benefit (Clark and Kavanagh, 1996). There are potentially significant equity issues with UBI however. While the policy does provide monetary resources to members of disadvantaged groups, financing the policy would likely require cuts to in-kind services that members of these groups would otherwise receive. Examples include education, mental health assistance, and other forms of counselling. If UBI entails the loss of these in-kind benefits, then it could have negative equity impacts.

Although the federal government has constitutional authority over taxation, income assistance (with the exception of EI) is majority-funded and administered by the provinces. Unless the policy option was administered entirely through the EI system, cooperation between the provinces and the federal government would be necessary. The federal government's role could be restricted to the provision of funding to the provinces, but the implementation of a UBI would still likely require national agreement on funding levels, benefit provision method, and other issues. This would be a complex undertaking from an administrative standpoint; however it also brings up politically and

³² Based on the current population of Canada aged 20+, expenditures for UBI at current median income would come to \$1.5 trillion.

socially sensitive issues about constitutional jurisdiction and values related to redistribution and the role of work in society.

Although redistributive policies do address the long-term policy problem, the discussion above suggests that they face significant fiscal, administrative, normative challenges. Resolving these issues will likely require a fundamental shift in attitudes towards the link between work and income, the desirability of large-scale income redistribution, and the role of government in society. Institutional change of this magnitude falls outside the scope of current policies for mitigating automation-driven structural unemployment over the next two decades; however the changing nature of the policy problem will require consideration of these issues in the long-term.

12. Conclusion

Increasing capital-labour ratios in almost all Canadian industries over the last four decades have not produced higher unemployment rates. This is due to the reallocation of labour away from industries where physical capital was labour-substituting into industries where physical capital was labour-complementing. This pattern is largely consistent with predictions of standard neo-classical labour models concerning the employment impact of automation in the long-run. However, recent evidence and signals indicate that new technologies are beginning to substitute for labour in industries and occupations not previously susceptible to automation. As technologies grow more sophisticated, Canada faces the prospect of historically high levels of structural unemployment due to declining demand for labour.

The issue of automation-driven structural unemployment has been the subject of much discussion and debate, however research to quantify the potential magnitude of the problem is only now appearing. My study contributes to this research by using previous work on occupation-level automation probabilities to estimate of the proportion of Canadian jobs that are at high-risk for automation over the next two decades. Two key findings that emerge are: first, between 40-50% of current Canadian jobs are at high risk for automation over the next two decades; and second, in the near-term, to compensate for job losses in low- and medium-skill occupations, the proportion of Canadians working in high-skill occupations will need to significantly increase.

Although dramatic, these findings have a number of limitations. First, if the capabilities of near-future technologies or the pace of their development have been overestimated, then I have overestimated the number of jobs at high-risk for automation. Conversely, if unforeseen technological breakthroughs that rapidly increase the scope of automation occur, then the estimations provided here could be too low. The estimates are contingent on assumptions about the near-future path of technology developments. Second, the estimates in my study assume that the existence of an automation

technology is sufficient reason for firms to adopt it.³³ There are many factors that have been found to influence firms' decision to adopt technologies once they are available. The number of jobs lost to automation is therefore likely lower when these factors are taken into account.³⁴ Third, the estimates provided in my study do not speak to the pace at which automation-driven job losses are likely to occur. There is no reason to assume that automation occurs incrementally. Jaimovich and Siu (2014) provide evidence that the disappearance of routine occupations over the last three decades was concentrated in recessionary periods. This suggests that the spread of automation technologies could follow a punctuated rather than incremental pattern.

Policies to manage automation-driven structural unemployment would benefit from further research on a number of issues touched on in this study. Additional research into long-term policy options to maintain Canadians' standard of living in the context of long-term declines in labour demand is also required.

Although the job-loss estimates provided in my study contain significant uncertainties, supporting evidence for the significance of problem is strong enough to justify serious policy consideration. In the near-term, establishing a national framework for education and skills-training should take priority; this will help maximize the number of Canadian workers who are able to transition to high-skill jobs as demand increases in the near-term for this type of labour. Concurrently, efforts should be made to consolidate federal SME support programs under the CDB, and research undertaken on the most effective ways to maximize the number of viable Canadian SMEs. As automation technologies begin to impact demand for high skill labour in the future, priority should be shifted to SME creation and development programs in order stimulate labour demand. Beyond the next two decades the policy objective will need to shift from minimizing structural unemployment to maintaining standards of living through

³³ As mentioned in Chapter 7, the cost of physical capital plays an important role in its adoption by firms; for the purposes of this paper it is assumed, not unfairly, that the cost of a given technology embodied in a unit of physical capital tends to fall over time.

³⁴ Because the estimates presented in this study do not incorporate occupations that Frey and Osborne (2013) found to be at low- or medium-risk for automation, overestimation due to the exclusion of other factors affecting the adoption of automation technologies could be counter-balanced by underestimation due to the exclusion of jobs lost in these occupations.

redistributive policies. Although the pace and pattern of labour automation in coming decades is not certain, a flexible policy response such this one will be required to effectively respond to the evolution of the policy problem.

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Appendix A

O*NET-NOC Mapping

Frey and Osborne (2013) categorize occupations with an automation probability assignment between 0 - 0.30 as 'low susceptibility', between 0.31-0.70 as 'medium susceptibility', and between 0.71-1 as 'high susceptibility'. To calculate the number of Canadian jobs that are highly susceptible to automation I use national occupational employment data from Statistics Canada for 2013, and occupational employment projections for 2022 by the Canadian Occupation Projection System (COPS). Occupations are classified according to the National Occupational Classification (NOC) scheme with additional groupings of occupations with small numbers of workers performed by the COPS group (Human Resources and Skills Development Canada, 2013 (a)).³⁵ The classification system contains 283 occupational categories at the 4-digit level.

Quantifying the number of Canadian jobs that are at high risk of automation based on the probability assignments of Frey and Osborne (2013) faces two challenges. First, the O*NET occupational classification system used by the researchers is based on the Standard Occupational Classification (SOC) system used in the United States, while occupational employment data from Statistics Canada is organized according to the National Occupational Classification (NOC) system. Because the NOC and SOC occupational titles are not identical, titles in the SOC system were matched to their closest equivalent in the NOC system.

The second challenge relates to level of aggregation. Automation probabilities are assigned at the detailed occupation level in Frey and Osborne (2013). The available NOC data I use is aggregated one level above the detailed occupational level. However because the detailed occupations falling into each of the 283 categories share the same

³⁵ Additional groupings made by the COPS team on the basis of occupational task content.

task profile³⁶, they also share very similar automation probability assignments in Frey and Osborne (2013). Thus the 4-digit NOC occupational category can be assigned the automation probability (or average probability) of the detailed SOC occupations falling under it without significantly distorting of the automation probabilities of the detailed occupations.

³⁶ According to Employment Services and Development Canada “The NOC provides an overall structure for classifying occupations according to the kind of work performed” (Human Resources and Skills Development Canada, 2014 (b)). Therefore, occupations falling under the same occupation category have very similar task profiles.

Appendix B

Industry-Level Shares of Total Employment and Share at High Risk of Automation

Occupational Grouping by Skill-Type (NOC)	% of Total Employment (2013)	% High Risk MEI (2013)	% High Risk PAEI (2013)	% of Total Employment (2022)	% High Risk MEI (2022)	% High Risk PAEI (2022)
Sales and Service	24.1	16.6	14.4	24.1	16.6	14.4
Business, Finance, Administration	17.7	13.9	12.7	17.4	13.4	12.2
Trades, Transport, Equipment Operators	15.1	10.4	8.5	14.6	9.8	8.1
Social Science, Education, Gov't Service, Religion	9.4	0.3	0.3	9.7	0.4	0.3
Management	8.6	0.2	0.1	8.6	0.2	0.1
Natural/Applied Sciences	7.4	0.6	0.5	7.7	0.6	0.5
Health	6.7	2.4	2.2	7.4	2.6	2.4
Unique to Processing, Manufacturing and Utilities	4.6	3.9	3.3	4.3	3.6	3.0
Art, Culture, Recreation and Sport	3.2	0.3	0.2	3.3	0.2	0.2
Unique to Primary Industry	3.1	1.5	1.3	2.9	1.4	1.3
Total	100	50	43.5	100	48.7	42.4

Appendix C

Occupation-Level Automation Probabilities

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N6433	6433/6434 - Airline Sales and Service Agents & Ticket and Cargo Agents	14	0.99	14	14
N1231	1231 – Bookkeepers	126	0.98	126	123
N1233	1233/1234/1235/1236 - Insurance Adjusters and Claims Examiners; Ins. Underwriters; Assessors and Valuators and Others	57	0.98	57	56
N1433	1433 - Tellers, Financial Services	99	0.98	99	97
N1471	1471 - Shippers and Receivers	133	0.98	133	130
N1232	1232 - Loan Officers	48	0.97	48	47
N1432	1432 - Payroll Clerks	49	0.97	49	48
N3220	3220 - Technical Occupations In Dental Health Care	36	0.97	36	35
N6451	6451 - Maîtres d'hôtel and Hosts/Hostesses	41	0.97	41	40
N6611	6611 - Cashiers	356	0.97	356	345
N8611	8611/8613/8616 - Harvesting, Aquaculture Labourers & Logging and Forestry Labourers	13	0.97	13	13
N1241	1241 - Secretaries (except Legal and Medical)	99	0.96	99	95
N1414	1414 - Receptionists and Switchboard Operators	168	0.96	168	161
N1431	1431 - Accounting and Related Clerks	184	0.96	184	177

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N5210	5210 - Technical Occupations In Libraries, Archives, Museums And Galleries	22	0.95	22	21
N8612	8612 - Landscaping and Grounds Maintenance Labourers	67	0.95	67	64
N9470	9470 - Printing Machine Operators And Related Occupations	16	0.95	16	15
N9484	9484/9485/9486/9487 - Assemblers and Inspectors, Other Mechanical and Electrical	34	0.95	34	32
N1111	1111 - Financial Auditors and Accountants	212	0.94	212	199
N1463	1463 - Couriers and Messengers	34	0.94	34	32
N4211	4211 - Paralegal and Related Occupations	57	0.94	57	54
N6213	6213/6214/6215/6216 - Other Services Supervisors (Executive Housekeepers; Cleaning; Others)	63	0.94	63	59
N6435	6435 - Hotel Front Desk Clerks	22	0.94	22	21
N7265	7265 - Welders and Related Machine Operators	109	0.94	109	102
N6251	6251 - Butchers and Meat Cutters, Retail and Wholesale	49	0.93	49	46
N7246	7246/7247 - Telecommunications Installation and Repair Workers & Cable Television Service and Maintenance Technicians	35	0.93	35	33
N7330	7330 - Other Mechanics	37	0.93	37	34

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N7620	7620 - Public Works And Other Labourers, N.E.C.	22	0.93	22	20
N1420	1420 - Office Equipment Operators	51	0.92	51	47
N1434	1434/1435 - Banking, Insurance and Other Financial Clerks & Collectors	63	0.92	63	58
N3413	3413/3414 - Nurse Aides and Orderlies & Other Aides and Assistants	318	0.92	318	293
N6231	6231 - Insurance Agents and Brokers	67	0.92	67	62
N6421	6421 - Retail Salespersons and Sales Clerks	544	0.92	544	500
N7294	7294 - Painters and Decorators	43	0.92	43	40
N9613	9613/9615 - Labourers in Chemical Products Processing and Utilities & in Rubber and Plastic Products Manufacturing	16	0.92	16	15
N9614	9614 - Labourers in Wood, Pulp and Paper Processing	20	0.92	20	18
N9616	9616/9619 - Labourers in Textile Processing and Other Labourers	46	0.92	46	42
N9617	9617/9618 - Labourers in Food, Beverage and Tobacco Processing & in Fish Processing	53	0.92	53	49
N7272	7272 - Cabinetmakers	14	0.91	14	13
N7322	7322 - Motor Vehicle Body Repairers	29	0.91	29	26
N7360	7360 - Train Crew Operating Occupations	11	0.91	11	10
N7370	7370 - Crane Operators, Drillers And Blasters	17	0.9	17	15

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N1242	1242/1244 - Legal Secretaries and Court Recorders and Medical Transcriptionists	26	0.89	26	23
N1440	1440 - Administrative Support Clerks	256	0.89	256	228
N6252	6252 - Bakers	37	0.89	37	33
N7413	7413 - Taxi and Limousine Drivers and Chauffeurs	43	0.89	43	38
N9440	9450 - Machine Operators And Related Workers In Fabric, Fur And Leather	21	0.89	21	19
N1472	1472/1473/1474/1475/1476 - Other Recording, Scheduling and Distributing Occs (Storekeepers and Parts; Production; Purchasing and Inventory; Dispatchers and Radio Operators; Transportation Route and Crew Schedulers)	115	0.88	115	101
N2250	2250 - Technical Occupations In Architecture, Drafting, Surveying And Mapping	58	0.88	58	51
N7314	7314/7315 - Railway Carmen/women & Aircraft Mechanics and Aircraft Inspectors	17	0.88	17	15
N9230	9230 - Central Control And Process Operators In Manufacturing And Processing	23	0.88	23	20
N6680	6680 - Other Elemental Service Occupations	50	0.87	50	44
N7295	7295 - Floor Covering Installers	20	0.87	20	17
N8430	8430 - Agriculture And Horticulture Workers	85	0.87	85	74

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N9490	9490 - Other Assembly And Related Occupations	90	0.87	90	78
N1224	1224 - Property Administrators	32	0.86	32	28
N3213	3213 - Animal Health Technologists	16	0.86	16	14
N6453	6453 - Food and Beverage Servers	191	0.86	191	164
N7412	7412 - Bus Drivers and Subway and Other Transit Operators	85	0.86	85	73
N9431	9431/9434/9436 - Sawmill Machine Operators & Other Wood Processing Machine Ops and Inspectors	18	0.86	18	15
N9510	9510 - Machining, Metalworking, Woodworking And Related Machine Operators	88	0.86	88	76
N1221	1221/1222 - Administrative Officers & Executive Assistants	269	0.85	269	229
N1411	1411/1413 - General Office Clerks & Records and File Clerks	77	0.85	77	65
N6411	6411 - Sales Representatives, Wholesale Trade (Non- Technical)	239	0.85	239	203
N7350	7350 - Stationary Engineers And Power Station And System Operators	25	0.85	25	21
N7450	7450 - Longshore Workers And Material Handlers	208	0.85	208	177
N8231	8231 - Underground Production and Development Miners	17	0.85	17	14

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N1450	1450 - Library, Correspondence And Related Information Clerks	197	0.84	197	165
N6651	6651 - Security Guards and Related Occupations	106	0.84	106	89
N7230	7230 - Machinists And Related Occupations	61	0.84	61	51
N7340	7340 - Upholsterers, Tailors, Shoe Repairers, Jewellers And Related Occupations	32	0.84	32	27
N8232	8232 - Oil and Gas Well Drillers, Servicicers, Testers and Related Workers	25	0.84	25	21
N9611	9611/9612 - Labourers in Mineral and Metal Processing & Metal Fabrication	29	0.84	29	24
N6621	6621/6623 - Service Station Attendants & Other Elemental Sales Occs	53	0.83	53	44
N6661	6661/6662 - Light Duty & Specialized Cleaners	254	0.83	254	211
N7291	7291/7292/7293 - Roofers and Shinglers; Glaziers & Insulators	39	0.83	39	32
N7380	7380 - Printing Press Operators, Commercial Divers And Other Trades, And Related Occupations,	29	0.83	29	24
N7430	7430 - Other Transport Equipment Operators And Related Workers	18	0.83	18	15
N8260	8260 - Fishing Vessel Masters And Skippers And Fishermen/Women	13	0.83	13	11
N6483	6483 - Pet Groomers and Animal Care Workers	25	0.82	25	21

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N7261	7261/7262/7263/7264/7266 - Metal Forming, Shaping And Erecting Occs (except Welders)	42	0.82	42	34
N7281	7281 - Bricklayers	14	0.82	14	11
N7421	7421 - Heavy Equipment Operators (except Crane)	89	0.82	89	73
N0121	0121 - Insurance, Real Estate and Financial Brokerage Managers	27	0.81	27	22
N1243	1243 - Medical Secretaries	33	0.81	33	27
N2241	2241 - Electrical and Electronics Engineering Technologists and Technicians	27	0.81	27	22
N6242	6242 - Cooks	180	0.81	180	146
N9482	9482 - Motor Vehicle Assemblers, Inspectors and Testers	35	0.81	35	28
N9483	9483 - Electronics Assemblers, Fabricators, Inspectors and Testers	23	0.81	23	19
N6271	6271 - Hairstylists and Barbers	100	0.8	100	80
N1461	1461 - Mail, Postal and Related Clerks	35	0.79	35	28
N7284	7284 - Plasterers, Drywall Installers and Finishers, and Lathers	31	0.79	31	24
N7411	7411 - Truck Drivers	292	0.79	292	231
N8241	8241 - Logging Machinery Operators	9	0.79	9	7
N9481	9481 - Aircraft Assemblers and Aircraft Assembly Inspectors	8	0.79	8	6
N9410	9410 - Machine Operators And Related Workers In Metal And Mineral Products Processing	24	0.78	24	19

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N9422	9422/9423 - Plastics & Rubber Processing Machine Operators	28	0.78	28	22
N1225	1225 - Purchasing Agents and Officers	46	0.77	46	35
N3211	3211/3212 - Medical Laboratory Technologists & Technicians and Pathologists' Assistants	50	0.77	50	39
N6452	6452 - Bartenders	34	0.77	34	26
N6641	6641 - Food Service Counter Attendants and Food Preparers	335	0.77	335	258
N8440	8440 - Other Fishing And Trapping Occupations	4	0.77	4	3
N5110	5110 - Librarians, Archivists, Conservators And Curators	14	0.76	14	11
N8420	8420 - Logging And Forestry Workers	11	0.76	11	8
N9421	9421/9424 - Chemical Plant Machine Operators & Water and Waste Plant Ops	20	0.76	20	15
N6670	6670 - Other Attendants In Travel, Accommodation And Recreation	37	0.75	37	28
N7282	7282/7283 - Cement Finishers & Tilers	21	0.75	21	16
N9440	9440 - Machine Operators And Related Workers In Textile Processing	9	0.73	9	7
N5230	5230 - Announcers And Other Performers	9	0.72	9	6
N6440	6440 - Tour And Recreational Guides And Amusement Occupations	21	0.72	21	15
N7271	7271 - Carpenters	125	0.72	125	90

NOC COPS Grouping Code	Occupation Name	Employment 2013 (000s)	Automation Probability	Vulnerable Jobs MEI (000s)	Vulnerable Jobs PAEI (000s)
N7442	7442/7443/7444/7445 - Other Installers, Repairers and Services	37	0.72	37	27
N7610	7610 - Trades Helpers And Labourers	145	0.72	145	104
N2243	2243/2244 - Industrial Instrument Technicians and Mechanics & Aircraft Instrument, Electrical and Avionics Mechanics, Technicians and Inspectors	16	0.71	16	11
N8410	8410 - Mine Service Workers And Operators In Oil And Gas Drilling	16	0.71	16	11
N7314	7321 - Motor Vehicle Mechanics, Technicians and Mechanical Repairers	124	0.7	124	87
N9460	9460 - Machine Operators And Related Workers In Food, Beverage And Tobacco Processing	80	0.7	80	56
	Grand Total	8632		8632	7509