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WHERE ARE THE ROBOTS?

The Surprising Deceleration of Technology in Canadian Workplaces

BY JIM STANFORD

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This research paper is published by PowerShare, a project to investigate workers' collective voice and agency in the future of work. Work is changing due to many forces: technology, business models, labour regulations and policies, and social attitudes. Will workers have a real say in what work becomes? Will they have the voice and power to meaningfully shape the future of work, and protect their interests?

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Introduction

PUBLIC DISCUSSION ABOUT THE "FUTURE OF WORK" HAS been strongly influenced by a widespread fear that accelerating technological change will result in the displacement of large numbers of workers by robots and other machines. New technologies — like robotics, machine-learning, new optical and mobility technologies, and nanotechnology — allow machines to undertake a wider range of productive tasks. It also allows them to be assigned duties which require flexibility and judgment, not just precise programmable instructions. Online videos and memes pay tribute to the incredible potential of robots in controlled laboratory environments.

Contrary to this public preoccupation, there is little evidence that the introduction of new technologies in Canadian workplaces has actually accelerated. As documented in this report, the pace of labour-saving technological change was faster in the second half of the twentieth century than more recently. Yet the spectre of mass technological unemployment did not dominate public discourse in those earlier times. Canadians in the booming postwar era were more likely to see technology as a source of opportunity, rather than something to be feared and resisted. Worker-friendly macroeconomic and social policies (like full employment, public education, and gradual reductions in working hours) helped to ensure that mechanization and technological change translated into better lives – rather than dislocation, unemployment, and inequality. That economic and institutional context underpinned a more optimistic attitude toward technology.

In contrast, today's labour market is a more hostile and insecure place, shaped by the ongoing struggle of workers to find and keep decent, stable jobs. Previous commitments to full employment, strong labour standards, and social inclusion have been re-

placed by a more deregulated, rough-and-tumble labour market. In this context of precarious work and pervasive insecurity, Canadians could be forgiven for concluding that robots and new technologies are just one more threat to their already uncertain livelihoods — rather than a potential source of higher productivity, higher incomes, and more leisure time. More uncertain economic and social conditions reinforce a more pessimistic public attitude toward technology and automation.

This paper suggests that concern over the potentially harmful effects of robots and automation misses an important prior question. The assumption that technology is in fact accelerating, let alone that it explains problems of job insecurity and unemployment, deserves critical scrutiny. The economic data assembled here does not indicate that the introduction of robots and other forms of automated machinery and technology is accelerating. To the contrary, by several different measures, the development and application of new technology by Canadian businesses is slowing down, not speeding up. Relative to previous periods in our economic history, and to the performance of other industrial countries, automation in Canada is proceeding at a surprisingly slow pace. And by some measures (such as the overall capital-intensity of production), the economy is going backwards.

Some might interpret this as good news: if the robots are *not* coming, then perhaps our jobs are safe after all. But far from justifying complacency, the glacial pace of innovation and technological transformation in Canada's economy attests to a deeper set of problems that, in turn, pose more obvious and imminent dangers to the quality and security of employment. The fact that investment in technology (both intangible know-how and tangible machinery) has been so weak for so long reflects a broader failure of Canadian business to innovate, accumulate capital, create jobs, and advance living standards. There is little risk that many Canadians will be thrown out of their jobs because of robots – and even if that risk existed, it could be managed with appropriate macroeconomic and labour market policies. On the other hand, there is a clear and present danger that too many Canadians are being consigned to low-tech, insecure, and poorly-paid jobs (largely in private service sectors like retail and hospitality, or gig jobs in transportation and delivery) as a result of the failure of Canadian business to adequately invest in new technology.

This paper begins, in Part I, with a review of some basic features of automation and mechanization, that help to put popular concerns about mass job loss and technological displacement in context. In the past, countervailing forces (including indirect labour, spin-off industries, growing output, and reduced working hours) generally offset job dislocation from automation and new technology. Part II of the paper then reviews nine empirical indicators that refute the usual assumption that work is being transformed by accelerating technology and automation. Investment and innovation in Canada are slowing down, not speeding up. This creates significant risks for the country's economic and social trajectory, and undermines both the quantity and quality of work available in the labour market. Part III considers four major consequences of this surprising technological slowdown for work and workers: for the quantity of

jobs, the composition of employment, the skill content of jobs, and labour productivity. Finally, Part IV addresses the implications of Canada's technological slowdown for economic and social policy. It recommends policy responses in several areas — including skills and training, macroeconomic policy, industrial strategy, and labour relations – that would both help to accelerate Canada's lagging technological performance, and ensure that the benefits of technology are shared more equally across society.

I. Automation in Perspective

ROBOTS CAN PERFORM A GREATER VARIETY OF TASKS, faster and better than humans, often for lower cost. And they never go on strike. So it's not surprising that public opinion has often worried about the impact of new technologies on jobs and economic security. In the early days of the Industrial Revolution, Luddite militants tried to sabotage new machines to avoid feared disemployment. Periodic waves of concern over technological displacement have been experienced ever since. For example, in the 1990s some researchers (such as Rifkin, 1995) predicted the "end of work." More recently, other forecasters (including high-tech billionaires like Richard Branson and Elon Musk) have suggested that mass technological unemployment will require a basic income system to prevent mass poverty.[1]

Some recent economic research has suggested that the job-displacing potential of new technologies (including artificial intelligence and machine-learning) could indeed be substantial – although other studies contradict this. Most famous are the projections of Frey and Osborne (2016), who projected that 47% of existing jobs in the US have a high likelihood of being displaced by automation within a decade. Other studies have been more cautious (such as Arntz et al., 2016), but still anticipate major disruptions in labour demand from technological change. Some Canadian research (such as Johal and Thirgood, 2016) also warns of the potential for mass displacement as a result of automation and other technological changes. Published research on the job-displacing effects of robots and automation continues to expand, but still hasn't found a consensus: some studies indicate very strong job-displacing effects at the firm or industry levels, while others report more benign results.[2]

[1] As reported, for example, by Clifford (2018).

[2] Other recent research in this area includes Acemoglu and Restrepo (2017); Adachi, Kawaguchi and Saito (2021); and Sequeira, Garrido, and Santos (2021).

While the adoption of new production technologies can certainly reduce direct employment in specific industries or occupations, there are many reasons why widespread technological displacement and unemployment across the broader labour market is unlikely to occur in practice. Indeed, it is hard to identify any clearly identifiable episodes of widespread technological unemployment in economic history. Why not? There are several countervailing factors which have helped to offset the employment-reducing effects of specific technologies:

- Most new machines and technologies require significant labour inputs in their own right, which offset at least some of the direct production jobs they ultimately may displace.[3] There is much human labour required to develop, engineer, manufacture, install, operate and maintain robots and other automated machinery. While this would cause a shift in the location of employment (with fewer direct production positions, but more indirect engineering and support roles), it is not clear that the total amount of labour demanded will fall substantially as these technologies are deployed.

- New technologies, once they are invented and deployed, typically open up opportunities for new forms of work and production that were not previously possible (or even conceivable). For example, consider the vast employment associated with developing and running programs and applications for smart phones. Hundreds of thousands of new jobs around the world have been created to do this work — opportunities that did not exist before smart phone technology came into widespread use. Similar spin-off job-creation will likely be experienced as a result of the spread of other new technologies. In this sense, new technologies can be a complement for employment, not just a substitute: implementing new technology can create work, not just destroy it.

- Appropriate macroeconomic, labour market, and skills policies help any labour displaced by new technology to be quickly and productively re-engaged in alternative vocations. Labour-saving technology boosts labour productivity, and thus creates the potential for faster growth of total output. Macroeconomic strategies to keep the economy operating at its full potential ensure a steady flow of new employment opportunities, including in brand new industries and occupations. That would offset some or all of the jobs eliminated by technology in other occupations. Supports for retraining, redeployment, relocation, and early retirement also help to smooth any resulting transitions.

[3] Indirect labour refers to work expended in the production of various inputs to a particular production process (also known as intermediate goods), including machinery, structures, and raw materials. Direct labour refers to the work performed directly in the production of any particular good or service.

- Historically, another buffer which helped to avoid employment reductions from new technology has been reductions in normal working hours. Mechanization makes it possible to produce more output with less work. One way to capture the benefits from that productivity is to reduce working hours: in that way, higher productivity leads to reduced labour demand, but spread evenly across the population of employed workers. Rather than producing concentrated pools of unemployment, automation would thus facilitate a gradual reduction in general working hours — and corresponding increases in leisure time. Shorter working time can be attained in many different forms: a shorter work day, a 4-day work week, longer annual vacations, opportunities for mid-career family and education leaves, earlier retirement, and other measures. Previous working time reductions allowed Canadian workers to enjoy more leisure time, as well as higher real incomes, as productivity advanced. In recent decades, progress toward shorter working hours has stalled; the issue has been further complicated by the inequality in working hours that has resulted from the growth of part-time and irregular work (whereby many Canadians work fewer hours than they would like to). Opinion polls indicate many Canadians support shorter working hours.[4] Resuscitating the goal of shorter working hours also carries potential environmental benefits, too — since capturing the benefits of productivity in the form of shorter work time rather than higher consumption implies less pressure on the natural environment (Hayden, 1999).

Together, these countervailing factors (new indirect labour required as an input to automated and mechanized systems; the emergence of new spin-off industries; growth in total output; and reductions in working hours) have prevented the emergence of widespread technological unemployment in the past. To be sure, some groups of workers have been negatively affected or displaced by new technologies — and that experience was made worse by the absence of supports and protections to help the resulting transitions. Concrete decisions about how technology is implemented and operated, and how its costs and benefits are shared among workers and other stakeholders, also shape how workers are affected. There is no reason to assume that technology alone will improve workers' lives, nor that technology will degrade them: it is human decisions, made in the context of particular social and economic conditions and power relationships, that determine whether new technology helps workers or hurts them. From an economy-wide perspective, however, mass technological unemployment has been long feared, but never experienced. Understanding the impacts of these countervailing forces, and the many factors that ultimately shape overall employment patterns, may help to alleviate public fears about the onset of job-destroying robots. It may also help to redirect concern to what is a more pressing and relevant concern: namely, Canada's failure to make the most of new technology to enhance work and lift living standards.

[4] For example, see Angus Reid Institute (2020).

II. The Non-Invasion of the Robots: Nine Surprising Trends

EMPIRICAL EVIDENCE SUGGESTS THAT THE POPULAR INFATUATION WITH robots, automation and artificial intelligence is increasingly at odds with Canada's rather less dynamic technological trajectory. Below we review nine empirical indicators which all suggest the pace of automation and technological change in Canadian workplaces has not sped up. To the contrary, Canada's recent innovation and technological performance has been much weaker than in previous periods, and lags well behind benchmarks set by other industrial countries. Indeed, by some measures, the technology-intensity of work in Canada is regressing.

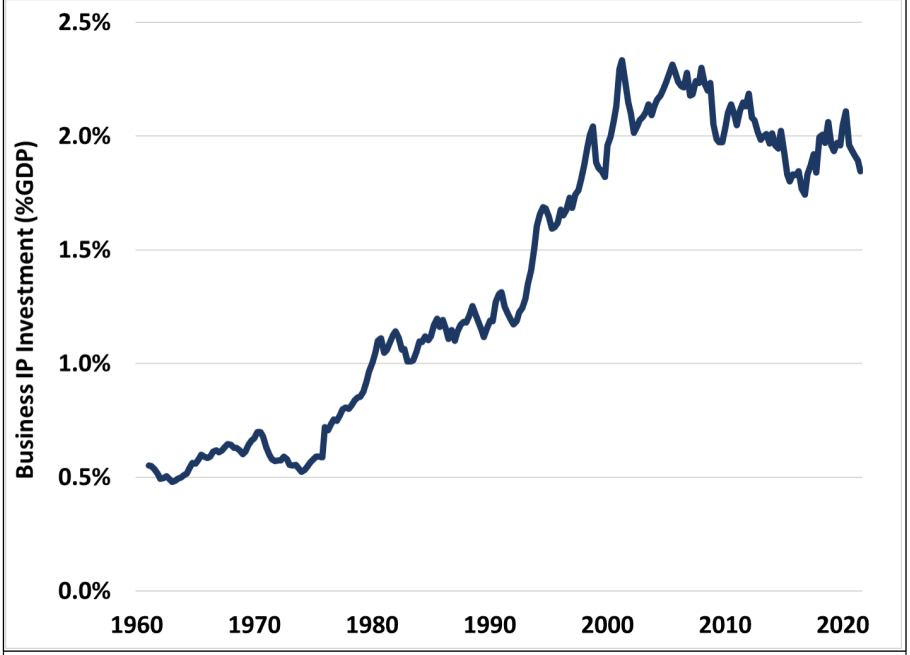
Slowing Business Investment in Innovation

Private enterprise is supposed to be the engine of innovation. Companies seeking more profitable products to sell, and more efficient processes to make them with, are supposed to relentlessly pursue new ideas that advance technology, raise productivity, and deliver economic gains to their owners, their workers, and their consumers. Given the dominant impression in popular culture that the juggernaut of new technology is reshaping our economy (and our lives), Canadian businesses must be leading the way to a promising high-tech future.

Unfortunately, the reality is quite the opposite. Figure 1 illustrates the trend in investments by Canadian businesses in innovation-intensive "intellectual property" over the last 60 years, measured as a share of national GDP. This category of investment includes assets like research and development projects, computer software, pharmaceutical formulae, and other intangible outputs of innovation effort.

Figure 1.

Business Investment in Innovation, 1960-2020



Source: Author's calculations from Statistics Canada Table 36-10-0104-01.

Beginning in the late 1970s, Canadian businesses dramatically stepped up their investments in intangible innovation. Those investments more than quadrupled as a share of GDP, from 0.5 percent of GDP in the 1960s and early 1970s, to a peak of 2.3 percent of GDP in the early 2000s. The last decades of the twentieth century were thus a period of genuine business focus on innovation. In the last two decades, however, the innovation activity of Canadian businesses has eroded markedly. By 2021 these investments equaled 1.8% of GDP: down one-fifth from its earlier peak.

If innovation is the wave of the future (and in some dynamic industries, that is certainly true), then Canadian businesses risk being left behind. They are reducing their investments in new knowledge, design, and programming — at a time when they should be ramping it up.

Canada's Lagging R&D Effort

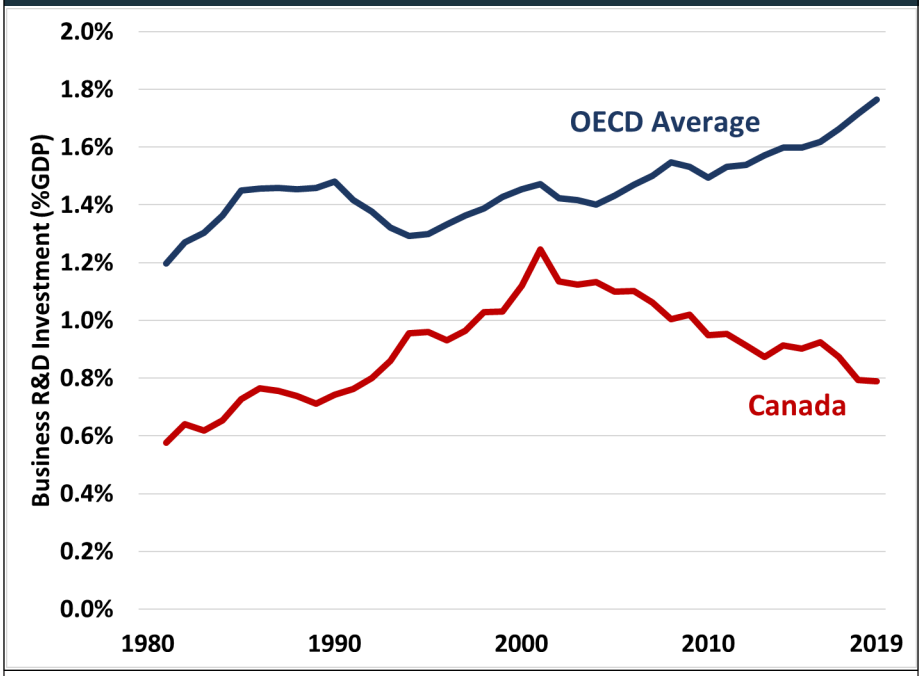
The pace of research and technology investment in Canada is significantly slower than in the past. Moreover, international data confirm that Canadian innovation activity is lagging further behind other industrial countries. Figure 2 compares Canada's business sector R&D spending as a share of GDP, to the average for OECD countries as a whole.[5] Canada's business R&D effort was closing the historical gap with other

[5] The OECD data on business R&D spending is defined more narrowly than the broader category of "intellectual property" investments illustrated in Figure 1 above, hence it corresponds to a smaller share of Canadian GDP (around 0.8% of GDP in 2019, compared to just under 2% that year for the broader category). Many activities measured within "intellectual property" investment (such as computer programming or minerals exploration) are not considered original R&D. The longer-run trends in both series are similar, however, indicating they reflect similar underlying weakness in business innovation activity.

industrial countries through the 1980s and 1990s. Canada gradually shed its traditional status as a technologically-lagging resource exporter, and Canadian firms were reaching the cutting edge of global technology. By 2001, Canada's business R&D effort (equal that year to 1.2% of GDP) was almost equal to the OECD average (1.4%). Since then, however, those two paths have diverged markedly. Businesses in other countries have continued to ramp up their R&D effort, but the innovation effort of Canadian firms has faded markedly. By 2019 (latest OECD data available), Canadian business R&D spending was less than half the average (as a share of GDP) of other industrial countries. Worse yet, the gap continues to grow.

Figure 2.

Business Investment in R&D, 1980-2019



Source: OECD Main Science and Technology Indicators.

Table 1 presents a more detailed international comparison of business R&D spending. In 2019, Canada ranked 26th among the 37 industrial countries that belong to the OECD. Canada's business R&D effort fell by one-third of a percentage point of GDP between 2000 and 2019. That is the 3rd worst decline in business R&D among all OECD countries. Across the OECD as a whole, in contrast, business R&D grew by the same amount (one-third of a point of GDP), reflecting a growing emphasis on innovation in global business strategies. Of the 11 OECD countries where business spends less on R&D than in Canada, most are less developed economies in Latin America and Eastern Europe. Relative to the leading industrial countries of Western Europe, North America, and Asia, Canada compares especially poorly. Leading innovators like Israel and Korea spend four or five times as much on business R&D as Canada. Japan spends over three times as much. Germany, Sweden, and the U.S. each spend more than twice as much.

Table 1.

Business R&D Spending, OECD Countries, 2019

Country	Business R&D Spending (% GDP)	Change Since 2000 (% pts)	Country	Business R&D Spending (% GDP)	Change Since 2000 (% pts)
Australia	0.90	.19	**Korea**	3.73	2.15
Austria	2.23	.99	**Latvia**	0.17	-.01
Belgium	2.04	.64	**Lithuania**	0.43	.30
CANADA	**0.79**	**-.33**	**Luxembourg**	0.60	-.86
Chile	0.12	na	**Mexico**	0.06	-.03
Columbia	0.11	.08	**Netherlands**	1.46	.48
Czech Rep.	1.20	.53	**New Zealand**	0.80	.45
Denmark	1.86	.38	**Norway**	1.14	.23
Estonia	0.86	.72	**Poland**	0.83	.60
Finland	1.83	-.46	**Portugal**	0.74	.54
France	1.44	.13	**Slovak Rep.**	0.45	.03
Germany	2.19	.50	**Slovenia**	1.51	.74
Greece	0.59	.44	**Spain**	0.70	.23
Hungary	1.11	.76	**Sweden**	2.44	-.32
Iceland	1.61	.16	**Switzerland**	2.25	.58
Ireland	0.91	.14	**Turkey**	0.68	.53
Israel	4.39	1.23	**UK**	1.19	.14
Italy	0.91	.41	**US**	2.27	.32
Japan	2.57	.50			
OECD Avg.	**1.76**	**.31**	**China**	1.71	1.17

Source: Author's calculations from OECD, Main Science and Technology Indicators.
Uses closest year when 2000 or 2019 data unavailable.

Even some emerging economies now invest more in R&D than Canada. For example, China allocated 1.71% of GDP to business R&D in 2019: more than doubling since 2010, and now almost equaling the OECD average. Chinese firms thus invest more than twice as much of their output in new technology as Canadian companies. The traditional assumption in comparative advantage economic theory that developed economies like Canada's will "naturally" specialize in high-tech industries, while supposedly "labour-abundant" and lower-wage economies like China's will tend to focus on simpler, labour-intensive production, is disproven. Like other newly industrialized countries before it, China's experience shows that successful high-tech industries are

built through deliberate, focused industrial policies and economic planning.[6] Without an urgent strategy to revitalize the technological vitality of Canadian business, Canada will be surpassed by China (and other developing economies) in the quest for high-tech economic development.

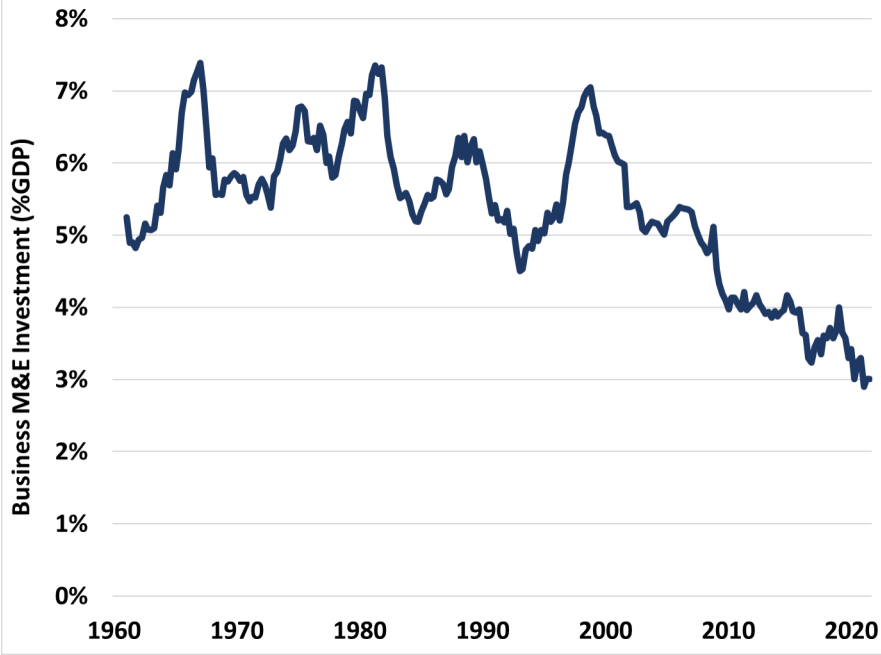
Slowing Business Investment in Machinery and Technology

It is not just in intangible research and intellectual property that the innovation effort of Canadian businesses is faltering. Applied innovation cannot occur in real workplaces without being embodied in tangible technology products: such as machinery, computers, electronic equipment, and — yes — robots. Rapid investment in new capital equipment and machinery is essential for businesses to capture the benefits of new knowledge, new products, and new production processes. Unfortunately, investment by Canadian businesses in new machinery and equipment (M&E) has been even weaker than their performance in the realm of intellectual property and R&D.

Figure 3 illustrates business capital investment in machinery and equipment, once again measured as a share of national GDP. In this case, the downward trend in business technology spending is more evident, more dramatic, and started earlier.

Figure 3.

Business Investment in Machinery and Equipment



Source: Author's calculations from Statistics Canada Table 36-10-0104-01.

[6] In recent years, the importance of active industrial policy and state-directed innovation strategies has been recognized by many economists; see, for example, Stiglitz et al. (2013), Rodrik (2008), and Mazzucato (2011, 2021).

Through the initial decades of the long postwar economic expansion, Canadian firms invested strongly and consistently in new equipment and technology. Machinery and equipment (M&E) investment fluctuated between 5 and 7% of national GDP from 1961[7] through the turn of the century, interrupted only temporarily by recessions in the early 1980s and 1990s. On average from 1961 through 2000, Canadian business machinery and equipment investment amounted to a vibrant 6% of national GDP each year.

Since the turn of the century, however, business investment in modern machinery and equipment — the most tangible manifestations of new technology – has plunged dramatically, with painful consequences for Canada's economic growth, productivity, and innovation. Business M&E spending fell by half over the following two decades. By 2021, it equaled just 3% of GDP: by far the lowest in Canada's postwar history, and less than half the average recorded over the second half of the twentieth century. The uncertainty and recession associated with the COVID-19 pandemic certainly exacerbated the weakness of business technology spending. But the negative trend was well-established long before then.

Ironically, the beginning of this long decline in business machinery investment in Canada coincides with the introduction of major reductions in business taxation at the federal and then provincial levels. This important policy change was predicated on the assumption that lower corporate taxes would inspire companies to invest *more* in new capital and technology, not *less*. Under Finance Minister Paul Martin, the federal corporate tax rate was cut from 28% to 21% starting in 2001; it was then cut further by subsequent Conservative governments to 15% by 2012. Provincial corporate tax rates were also reduced in several provinces during this time. Together this resulted in a reduction of over one-third in the combined federal-provincial corporate tax rate, corresponding to tens of billions of dollars in foregone annual revenue to each level of government.[8] Ironically, these historic tax cuts have been associated with unprecedented *weakness* in business capital spending on technology; this should motivate a deep rethinking of the rationale and effectiveness of corporate tax cuts as a tool for eliciting business investment.

Slowing Overall Business Capital Spending

The preceding data indicate that investment by Canadian businesses in modern technology (both intangible intellectual property and tangible M&E) has weakened markedly in recent years, even as popular infatuation with robots and artificial intelligence reached a fever pitch. That worrisome slowdown in high-technology investment is matched by a parallel if less dramatic weakening of business capital spending in general — including on capital assets such as buildings and structures.

[7] Statistics Canada's modern quarterly national accounts system goes back to 1961. Other historical data (eg. Statistics Canada, 1983) suggest that business machinery and equipment investment was even stronger earlier in the postwar era: averaging 7.1% of GDP from 1946 through 1960.

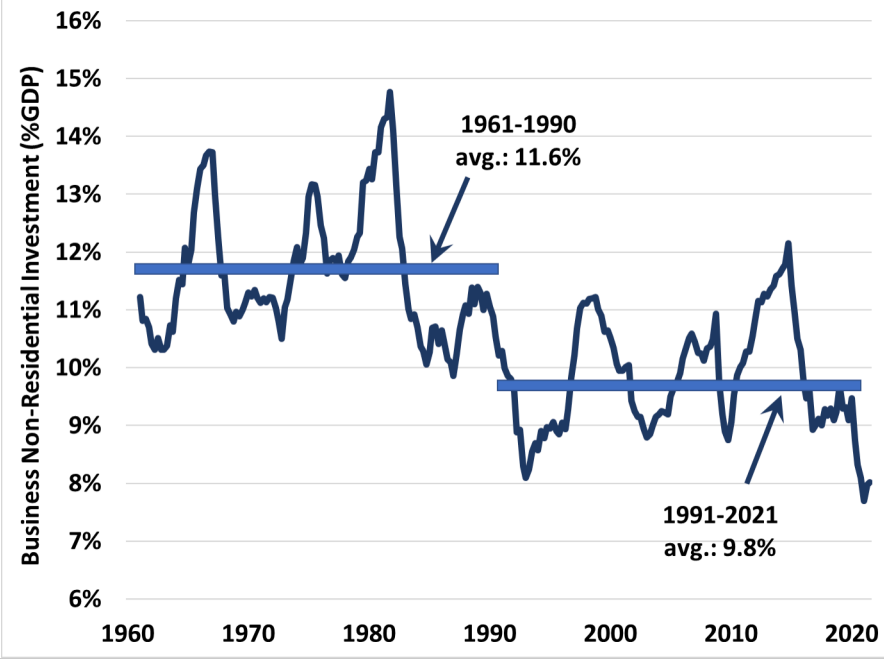
[8] See Stanford (2011, 2020) for an overview of the tax cuts and their lack of effectiveness in stimulating business capital investment.

The observed weakness of business investment, across all asset forms, suggests a deeper underlying problem in the dynamics of Canadian economic growth and private sector vitality.

Figure 4 illustrates total business non-residential capital spending in Canada, as a share of GDP. Not surprisingly, business investment shows a strong cyclical pattern: peaks are associated with economic booms, and troughs with slowdowns and recessions. Indeed, business capital spending is one of the most volatile components of GDP, and is often seen as a leading indicator of economic activity for this reason. Across these repeated cycles, from 1961 through 1990, total non-residential business capital investment averaged about 12% of national GDP (about half of which was M&E, the rest allocated to other assets including buildings, structures, and intellectual property). These injections of spending power provided a reliable and powerful push to growth and job-creation. Strong business investment also facilitates structural change in the economy, the emergence of new industries, and the application of new technologies.

Figure 4.

Business Investment in Non-Residential Capital



Source: Author's calculations from Statistics Canada Table 36-10-0104-01.

After the harsh recession of the early 1990s, Canadian business capital investment shifted to a lower baseline, and has not recovered since. Non-residential capital spending since 1990 has averaged under 10% of national GDP — still marked by sharp swings corresponding with macroeconomic cycles (including the recessions of

1991-92, 2008-09, and 2020-21). At times, the sustained declines in intellectual property and machinery investments (illustrated above in Figures 1 and 3) were partly offset by increased investment in traditional "bricks and mortar" capital assets: including buildings, business infrastructure, and other structures. Spending on non-residential structures thus moderated the decline in overall non-residential capital spending, but the overall trend has nevertheless been negative.

In particular, huge investments in large structures and construction projects associated with petroleum extraction were a key component of overall investment spending in the years from 2001 through 2014 (discussed further below). In 2014, total business investment reached its highest share of GDP (over 12%) since the early 1980s, led by enormous petroleum projects. After the global oil price collapse of 2014, however, energy investments also declined sharply, and the broader weakness of Canadian business capital spending then became more pronounced. Even before the COVID-19 pandemic, total non-residential capital spending was languishing. Then with the pandemic and resulting recession, total business capital investment fell to below 8% in 2021 — a postwar record low.

In summary, Canada's business investment performance was already historically weak even before the pandemic. Significant and sustained reductions in innovation and machinery spending were moderated in some years by spending on non-residential structures (especially in the petroleum industry). More recently, however, the erosion of spending on those non-residential structures has amplified the longer-run decline in overall capital spending. Both the quality and the composition of business capital spending in Canada therefore raise major concerns about the country's future economic vitality.

Energy and Non-Energy Capital Spending

As noted above, the booms and busts of petroleum industry investment have had a major impact on overall Canadian business capital spending. There is no doubt that capital spending in the petroleum industry has at times been a powerful boost to aggregate demand and employment in petroleum-producing regions of the country. From the perspective of Canada's long-run economic development, however, over-reliance on extractive industries (and petroleum and other fossil fuels, in particular) raises several concerns. The petroleum industry is a weak performer in innovation spending: its R&D spending is well below the average for other Canadian industries.[9] Most capital spending in petroleum goes for large construction projects, not machinery and equipment (which is more technology-intensive). Over the last decade, M&E accounted for just 12% of total petroleum industry capital spending, compared to 30% for other industries.[10] That emphasis on construction limits the positive technological spin-offs that usually flow from business investment. Finally, of course, fossil

[9] In 2018, latest data available, the oil and gas extraction industry allocated 0.8% of its total revenues to research and development, compared to 2.1% for all Canadian business (Statistics Canada Table 27-10-0358-01).

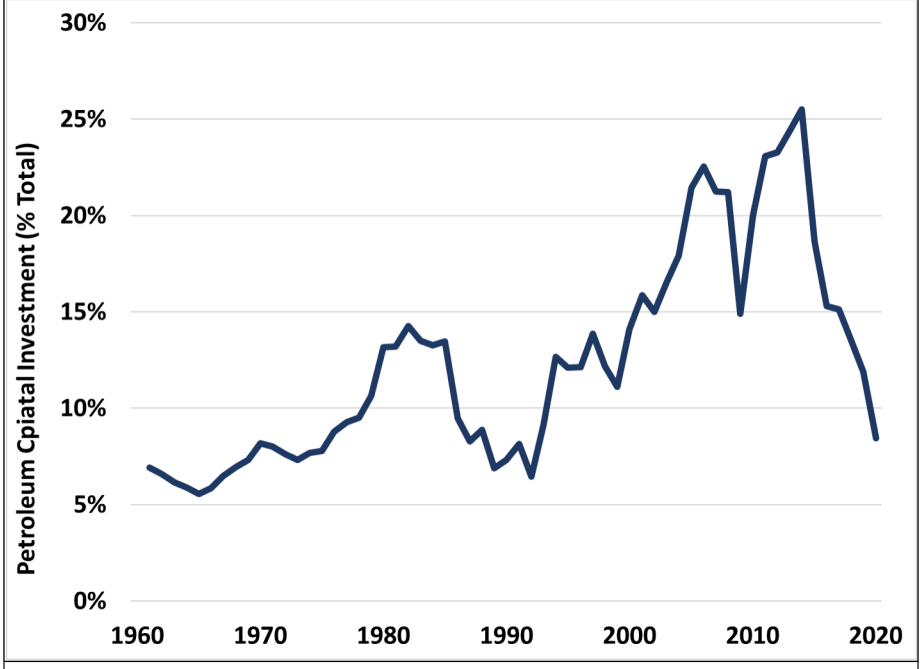
[10] Author's calculations from Statistics Canada Table 36-10-0096-01.

fuel industries face an ultimate binding constraint: this industry will shrink and eventually phase-out as the global economy responds to climate change. Whether pushed by domestic climate policy or simply by the evaporation of global demand for fossil fuel products, it is inevitable that these industries will decline in coming decades. For all these reasons, efforts to improve investment, innovation, and growth in non-fossil-fuel industries must be central to any broader strategy to rekindle technological momentum in Canada's economy.

Figure 5 portrays capital spending by the petroleum industry as a share of total business capital spending in Canada.[11] Through the second half of the twentieth century, the petroleum industry typically accounted for a small share of total business capital spending in Canada: between 5 and 7% of total investment. That share rose temporarily during the energy booms of the early 1980s and early 1990s. After 2001, however, surging global commodity prices and the accelerated development of Alberta's capital-intensive bitumen industry boosted the petroleum share of total business investment dramatically. At peak, in 2014, just before the collapse of global oil prices, petroleum accounted for over 25% of all business capital investment in Canada. In the wake of falling oil prices and the global shift in energy demand away from fossil fuels, that fell back toward a normal historical range – amounting to 8% of total business capital spending by 2020.

Figure 5.

Petroleum Capital Spending as Share Total, 1961-2020



Source: Author's calculations from Statistics Canada Table 36-10-0104-01.

[11] This data includes capital spending in the conventional and non-conventional (bitumen) extraction industries, petroleum services, and petroleum refining.

The boom in petroleum investment from 2001 through 2014 exerted a negative influence on business capital spending in other sectors, including innovation, R&D, and M&E investments. There are several channels through which the petroleum boom squeezed out capital investment in other, more technologically-intensive sectors. The supply of financial capital to the business sector is not infinite; the enormous sums required for petroleum investments during this time affected both the availability and the price of finance for other industries. The shift in the attention of Canada's business leaders toward petroleum expansion also distracted from entrepreneurial focus on other, more technologically-intensive opportunities. Finally, the macroeconomic side-effects of the petroleum boom (particularly its effect on the Canadian exchange rate, which was pushed far above fair-value) negatively impacted other trade-exposed industries (like manufacturing) that are more innovation-intensive.

For all these reasons, Canada's historic over-reliance on extraction and export of non-renewable resources (and petroleum in particular) has been a key factor in our technological underperformance. Other countries which were not "blessed" with large endowments of non-renewable resources (like Japan, Korea, and several European countries) were forced to develop other industries. It is not coincidental that those countries now greatly outperform Canada in investment in business innovation and use of machinery. The recent surge in global energy prices is rekindling hopes in the petroleum industry that another energy boom may be coming. From the perspective of Canada's broader technological progress, however, another upsurge in petroleum investments would be a negative development. The country would be better serviced by a focus on other industries (including renewable energy) with greater technological content, and a longer lifespan.

Real Estate and Capital Spending

Another sign of misallocation of capital resources in Canada's economy has been the dramatic surge in residential capital spending in recent years. Housing prices in Canada escalated rapidly over the last decade, spurred by the low interest rates that have prevailed since the global financial crisis of 2008-09 (which fell even lower during the COVID-19 pandemic). Property price inflation, and resulting large profits in home construction, have attracted the attention of investors and companies. So the real estate bubble has resulted in a growing share of total private capital investment being allocated to residential construction.

Access to affordable, quality housing is an important component of Canadians' overall standard of living. More home construction could help to alleviate the crisis in affordability that afflicts many Canadian cities — depending on the type of housing constructed, and other policies which influence affordability.[12] Construction is an important source of employment and GDP, with spillover benefits flowing to other in-

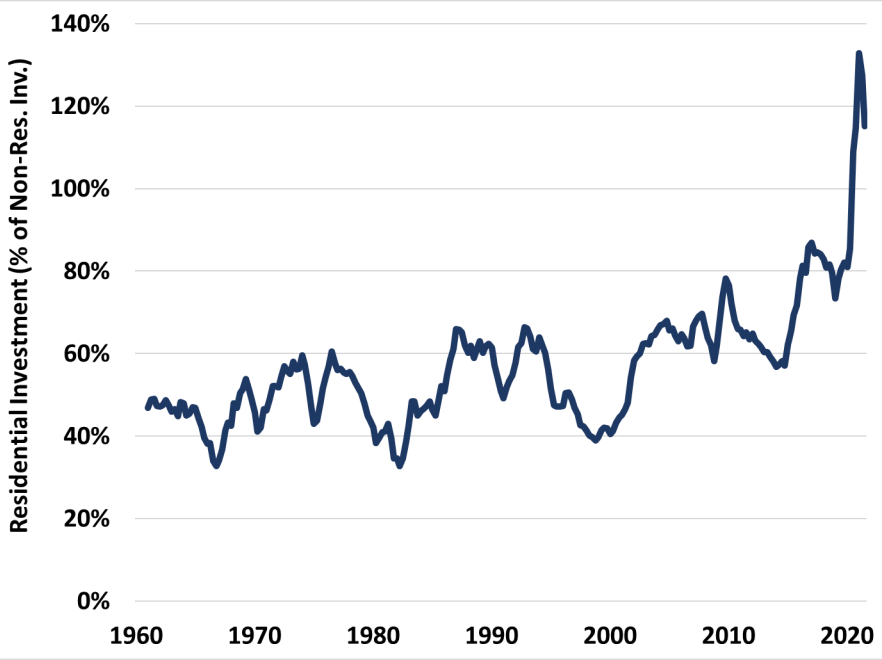
[12] Speculative for-profit housing development has indeterminate impacts on housing affordability, since it tends to emphasize higher-margin luxury developments over affordable options (including rental housing). A larger emphasis on supply of non-market housing of various kinds (including public housing, housing cooperatives, and housing trusts) would have more direct benefits for affordability; see Lee (2021) for discussion.

dustries which supply the construction sector with materials and services. However, like the petroleum sector, construction invests a very small portion of revenues in research and development: just 0.3% in 2019, about one-sixth the average for Canadian businesses as a whole.[13] And the construction boom has diverted both capital and management attention away from other, more technologically dynamic sectors. Hence the growing footprint of residential construction has likely had negative impacts for business investment in other sectors with more technological potential.

The reallocation of private capital spending in Canada toward housing and away from other more technology-intensive activities is clearly visible in empirical data. Figure 6 shows the ratio of capital spending on residential projects, to the total amount of non-residential capital spending (in all forms) by Canadian business.[14] Throughout the second half of the twentieth century, residential investment fluctuated between 40% and 60% of the volume of non-residential private capital investment. Housing's share of all private capital spending increased somewhat after the turn of the century (averaging 61% of non-residential spending through the 2000s). But the footprint of property developments then surged with the advent of ultra-low interest rates after

Figure 6.

Ratio of Residential to Non-Residential Capital Spending, Canada, 1960-2021



Source: Author's calculations from Statistics Canada Table 36-10-0104-01.
Private capital spending only.

[13] Author's calculations from Statistics Canada Table 27-10-0358-01.

[14] The data on business investment presented above (including innovation, M&E, and total non-residential investment) included only non-residential spending.

2008. By 2021, reflecting both booming housing construction and weak non-residential capital spending, the ratio reached 120%. For the first time in history, Canada's economy invested more in housing than in all non-residential capital projects put together.

The growing focus on residential investment in Canada's overall capital spending profile reflects many problems in Canada's economy — including the distorting impacts of near-zero interest rates and rapid house price inflation, and the structural weakness of Canadian businesses in more technology-intensive activities. Implementing more equitable and sustainable housing policies, and reigning in the excessive growth of market housing prices, would have multi-dimensional benefits for Canada's technological progress in other industries. It would free up both capital and business attention to develop a more balanced and technologically successful set of industries. It would also ensure that employers in high-tech hubs in Canada are not constrained by unaffordable housing prices presently faced by their prospective workers.

Eroding Capital Stock

One surprising and worrisome consequence of the very slow pace of business M&E investment in recent years is that new investment has not even been sufficient to offset wear and tear of the existing capital stock. The result is an unprecedented shrinkage in the net stock of tangible equipment that Canadian workers use to do their jobs. Instead of the robot revolution leading to a more abundant "toolkit" for workers, the country's accumulated capital stock (after depreciation) is now actually shrinking.

Figure 7 illustrates the balance between new M&E investment in Canada (including robots!), and the estimated depreciation recorded as older machinery wears out or becomes outdated. An economy must invest a certain amount each year just to maintain its capital stock in good working order. That amount is estimated on the basis of the type of assets being depreciated, assumptions about working life, and other parameters.[15] Gross investment is defined as total spending on new capital; net investment is the amount after deducting the costs of depreciation. An increase in the net capital stock (that is, positive net investment) reflects a process of capital accumulation: with more being allocated to new assets than required simply to offset wear and tear.

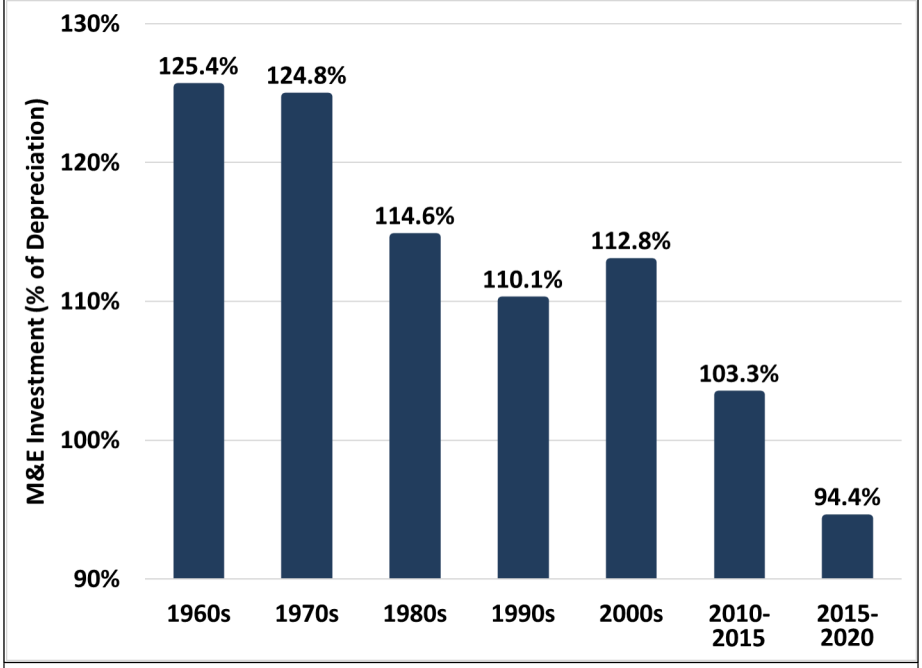
Figure 7 portrays gross new M&E investment as a proportion of estimated M&E depreciation in each period. During the expansionary 1960s and 1970s, new investment easily exceeded wear and tear on existing assets, by an average of around 25% each year; as a result, the net capital stock (after depreciation) grew robustly, and Canadian workers enjoyed a more abundant "toolkit" of tools and equipment to work with. The pace of net capital accumulation slowed down later in the century, but remained consistently positive — with gross investment exceeding depreciation by 10-15% each

[15] Figure 7 utilizes a geometric depreciation method (the most common in accounting), but the trend is similar if other methods (such as straight-line or hyperbolic) are utilized.

year. From 2010 to 2015, net M&E investment slowed to a snail's pace: equal to around 3% of gross investment each year. Ominously, since 2015 net investment has turned negative. In other words, the amount invested by Canadian businesses in new M&E no longer even offsets the wear and tear on the existing stockpile of equipment.

Figure 7.

Ratio of Machinery and Equipment Investment to Depreciation, 1960s to 2010s



Source: Author's calculations from Statistics Canada Table 36-10-0096-01.

For the first sustained period in Canada's postwar history,[15] Canadian businesses are not investing enough in new machinery and equipment to maintain the net capital stock, which has thus begun to shrink. In real terms, the net M&E capital stock (after depreciation) declined by 7% from 2014 (when it peaked) to 2020 (latest data available). The contraction in M&E capital was made worse by the effects of the COVID pandemic and resulting recession. But the pattern of negative net investment was well-established before the pandemic hit.

The Capital-Labour Ratio is Falling

The failure of businesses to even maintain the existing stock of machinery and equipment, let alone add to it with new technologies (like robotics), produces another unexpected and worrying outcome: the overall ratio of capital to labour in the economy is also falling. In other words, the aggregate quantity of "tools" which a typical worker

[16] Before 2015, gross investment fell below depreciation only temporarily during economy-wide recessions (such as 1993 or 2009), when business investment was cut for cyclical reasons.

uses in the course of their job is shrinking, and hence economic activity in aggregate is becoming less capital-intensive.

This trend runs directly against the assumption that new technology is replacing labour in various applications and occupations. If workers were truly being replaced by machines, this would unambiguously lift the amount of tangible capital employed in production, relative to employed labour. Automation implies substantial increases in the amount and value of machinery in use; the numerator of the capital-labour ratio must rise. Moreover, if machines replace labour (rather than complementing it), then employment (the denominator of the capital-labour ratio) would decline. Through both a rising numerator and (possibly) a shrinking denominator, the ratio of capital to labour used in the economy should unambiguously rise.

It is both curious and concerning that this is not occurring in Canada. To the contrary, the aggregate ratio of capital to labour in use in the economy has been falling since 2016. Sustained decline in the capital-labour ratio is unprecedented in Canada's post-war economic history.[17] Indeed, long-term increases in the capital-labour ratio are a universal hallmark of economic development: countries lift their living standards over time precisely by accumulating capital and technology[18] in order to expand the quantity and quality of potential output. For a developed country to experience a continuing decline in the amount of capital used in production relative to labour is unusual and worrisome. That Canada's capital-labour ratio has been falling for several years, suggests deep structural weakness in the processes of investment and technological change in the national economy.

Figure 8 illustrates the aggregate ratio of Canada's real net capital stock (measured after depreciation, and expressed in inflation-adjusted terms) to the number of Canadians employed. After 2015, weak non-residential capital spending caused the net capital stock (after depreciation) to stagnate.[19] Yet employment continued to increase (disrupted temporarily by the COVID pandemic). Consequently, the overall capital-labour ratio in the economy has declined. It fell by a cumulative total of about 3% between 2015 and 2019.[20]

The decline in the net stock of M&E capital used in production in Canada relative to the number of employed workers has been more dramatic, because in this case the net stock of real capital has been shrinking in absolute terms. Figure 9 illustrates the net real M&E capital stock per employed worker — a more precise measure of the

[17] Previously the capital-labour ratio declined only temporarily as the economy recovered from recessions: which suppressed the capital stock (due to weak business investment), and were followed by periods of rapid employment growth (as the recovery took hold). Once recovery was complete, the capital-labour ratio began to increase again.

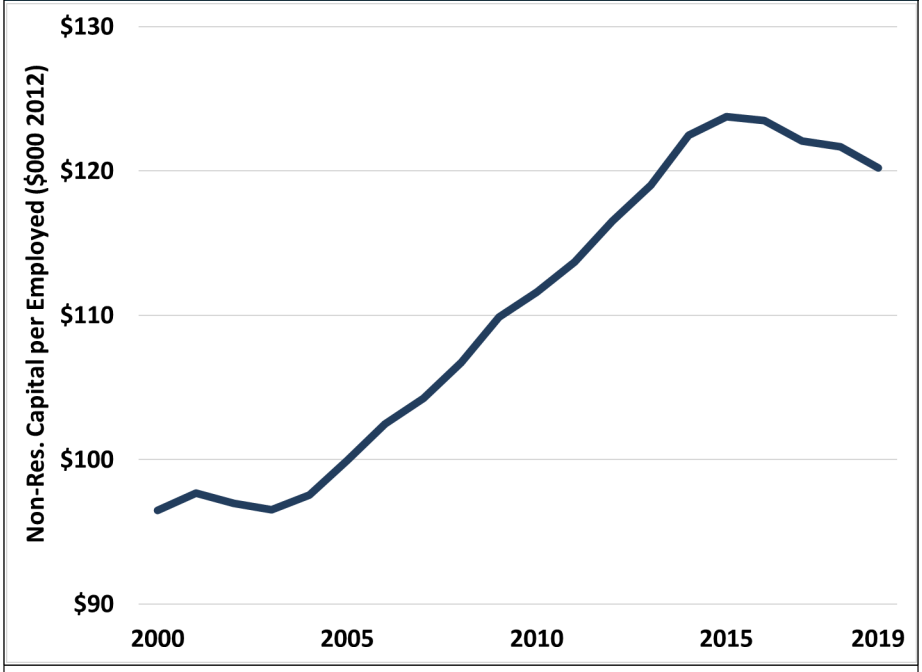
[18] Along with the knowledge and skills to effectively use that technology, sometimes called "human capital."

[19] Unlike the real net M&E capital stock (which has been declining for several years, as described in Figure 7), the total real net non-residential capital stock (including all assets) has stagnated but not contracted.

[20] The aggregate capital-labour ratio increased in 2020 as a result of the sharp decline in employment during the COVID-19 pandemic; that increase was reversed in 2021 as employment recovered to pre-pandemic levels.

Figure 8.

Aggregate Capital-Labour Ratio, 2000-2019



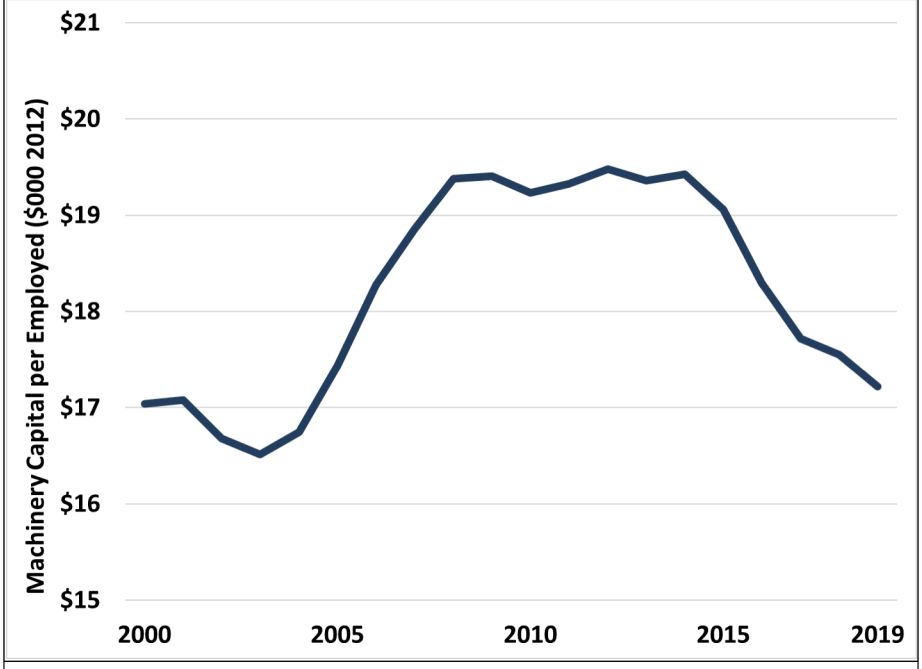
Source: Author's calculations from Statistics Canada Tables 36-10-0096-01 and 14-10-0327-01.

intensity of machinery use. This ratio should reflect the pace of labour-replacing technological change: according to the standard "robots are coming" narrative, if humans are being replaced by machines, this ratio should rise rapidly.

Since the real stock of net capital equipment (after depreciation) is shrinking, combined with normal employment growth this has produced a two-fold decline in the capital-labour ratio. After doubling from 1960 through 2008 (interrupted by recessions and subsequent recoveries), the ratio of M&E per worker stagnated for several years after the global financial crisis, and then turned down sharply after 2014. The machinery-labour ratio has since declined by a cumulative total of over 11%. In other words, the typical Canadian worker uses 11% less machinery and equipment to do their job with today, than they did in 2014. So much for robots taking our jobs: to the contrary, it seems that labour is becoming more important in the productive process. And while this trend confirms that robots are not taking over, for anyone concerned with the long-term prospects of economic development, innovation, and prosperity, it is not a good sign at all.

Figure 9.

Net Machinery and Equipment Capital per Worker, 2000-2019



Source: Author's calculations from Statistics Canada Tables 36-10-0096-01 and 14-10-0327-01.

Good Robots are Hard to Find (in Canada)

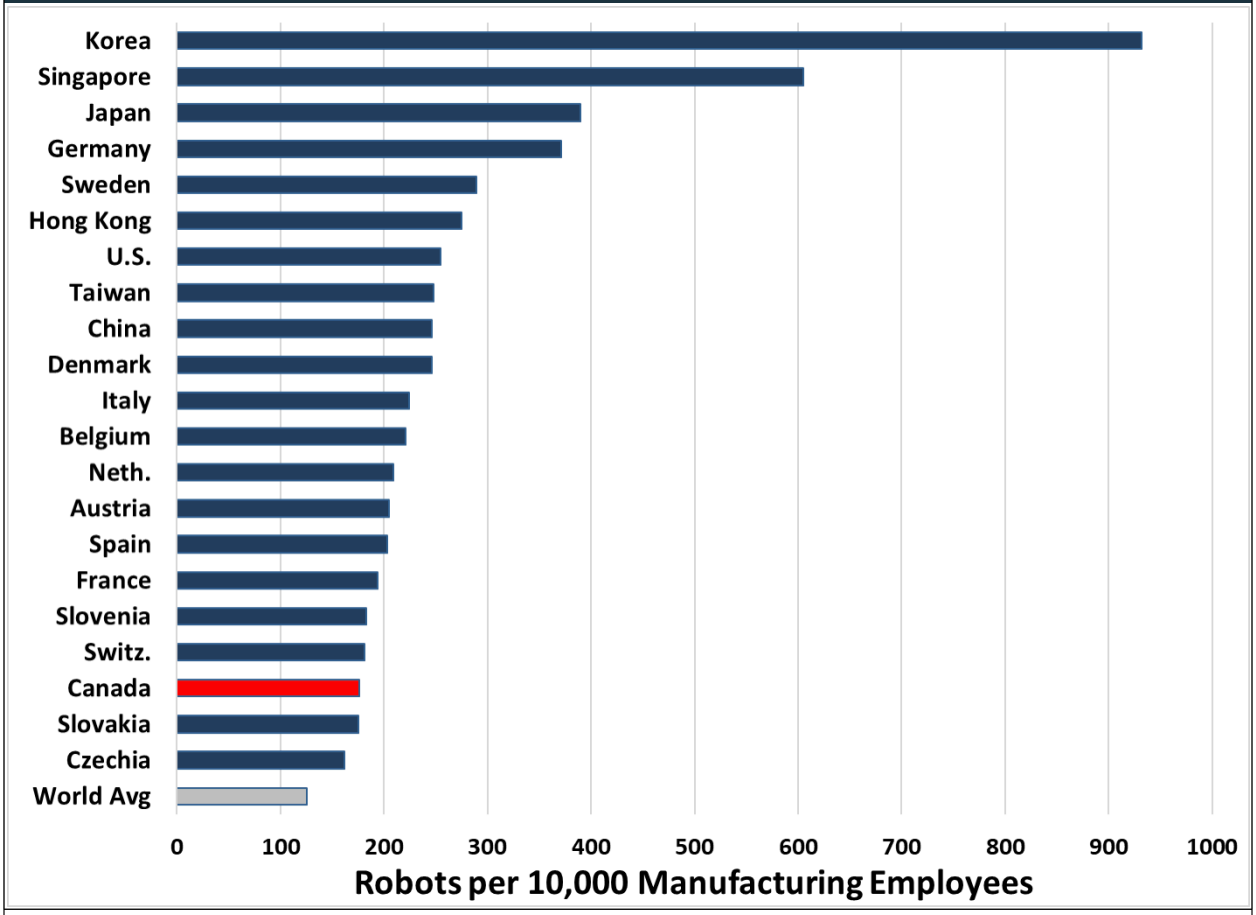
The preceding discussion has presented empirical evidence on several broad trends in innovation and investment in new technology in Canada: including investments in intangible intellectual property and R&D, and spending on tangible capital (most importantly new machinery and equipment). Robots are just one specific example of automated technology: a programmable machine which can conduct relatively complex tasks, involving motion and manipulation of other objects. Robots are not, of course, the only way workers can be replaced by machines. But the prospect of workers losing their jobs, replaced by robots which can do the job faster and more accurately, naturally evokes fear about machines "taking over", and exerts a powerful influence in popular culture. This concern is centuries old — epitomized by the lyrics to the folk ballad *John Henry*, about a railway worker who ultimately died trying to keep up with a pile-driving machine.

So let us turn our attention more specifically to the use of actual robots in Canada's economy. Once again, it turns out that hype about the onward march of automation is overstated. Instead of seeing mass numbers of workers replaced by robots, a bigger problem seems to be the very slow pace of automation and robotization undertaken by Canadian employers.

Worldwide data on the use of industrial robots is published by the International Federation of Robotics.[21] The Federation's statistics confirm an accelerating shift to robot-based technology in many countries. There were over 3 million installed industrial robots in use in various countries around the world in 2020. Annual installations of industrial robots have doubled since 2013. Almost 400,000 new robots were installed worldwide in 2020, despite the COVID-19 pandemic. The Federation expects annual installations to continue accelerating, reaching over 500,000 per year by 2024.

Figure 10.

Worldwide Use of Industrial Robots, 2020



Source: International Federation of Robotics (2021).

[21] The IFR also conducts research into the use of robot-like devices in various consumer and home-based applications (such as automated vacuum cleaners, etc.); we focus here on commercial and industrial applications.

Figure 10 portrays the countries with the greatest intensity of industrial robots, ranked by the number of robots used per 10,000 manufacturing workers. Korea leads all countries, with over 900 robots for every 10,000 workers. Singapore is second with around 600 robots per 10,000 workers. Japan, Germany, and Sweden also have relatively widespread robot use (around 300 robots per 10,000 workers), followed by other technology-intensive manufacturing countries (such as the U.S., China, Taiwan, Denmark, and Italy).

In 2020 Canada had 176 installed robots per 10,000 manufacturing workers. That ranked 19th among countries in the intensity of industrial robot use. Canada's rate of installation of new robots is slowing, and our ranking in robot use among countries is falling accordingly: down from 12th place in 2015, just 5 years earlier. This reflects the deeper weakness in innovation and technological capabilities among Canadian firms, as described above.

The worldwide average utilization of robots in 2020 was estimated at 126 robots per 10,000 workers.[22] So Canada's economy still uses more robots than the world average, but the difference is narrowing. Table 2 indicates that Canada's use of robots is growing more slowly than other countries. Robot intensity (per 10,000 manufacturing workers) increased by 29% in Canada between 2015 and 2020, compared to an 83% rise in the world average.

Table 2.

Canada's Slowing Robot Adoption, 2015-2020

	Canada Robot Intensity[1]	World Robot Intensity[1]	Canada as % World	World Rank
2015	136	69	197%	12
2020	176	126	140%	19
Change	29.4%	82.6%	-57 pts.	-7

Source: Author's calculations from International Federation of Robotics (2016, 2021).

1. Industrial robots per 10,000 industrial workers.

Canada now even lags behind China: which installed over 600,000 industrial robots in the last four years, and in 2020 used 246 robots per 10,000 workers, 40% more than Canada. This is despite China's supposed abundance of "cheap" labour — which, according to conventional economic theory, should reduce the incentive for employers to replace workers with machines. But it isn't automatic market mechanisms driving China's rapid adoption of robotics: it is deliberate industrial strategies implemented by government and business, aimed at lifting China's prowess in advanced technology.

[22] The IFR data does not include data from some less developed countries where robots are rare, and hence the true worldwide average utilization rate is lower than this.

Not coincidentally, the countries which lead the world in use of robots in production, also lead in exports of sophisticated, high-value manufactured products (produced with the help of those robots). Those countries also demonstrate generally strong labour market outcomes (with low unemployment and faster wage growth), in part because of their more successful engagement in global trade. So on a global basis, it seems that greater automation (including robotization) is associated with more and better jobs, not with mass displacement and technological unemployment.

The fact that Canada is not participating fully in the robotics revolution attests to broader weakness in the innovation capacity of Canadian businesses, and their failure to invest in new technologies and advanced products. The decline in Canada's automotive manufacturing industry in recent years is a particular manifestation of that worrying trend. In 1999 Canada ranked as the 4th largest auto assembler in the world; in 2020 we ranked 12th. Auto production fell by more than half over that time, due to assembly plant closures and the relocation of auto production to Mexico and other low-cost locations. Automotive manufacturing is traditionally a leading site for application of robotics (although it was passed in 2020 by the electrical and electronics industry as the largest global robot user). The erosion of automotive manufacturing operations in Canada, and the failure of Canadian business to establish strong footholds in other high-tech industries (such as electronics), helps to explain Canada's fading performance in the use of robots.

Robotization is just one relatively specialized dimension of the broader phenomena of automation and mechanization, but it is an important indicator of the general technological capacity of both firms and countries. And Canada's weakening performance in adopting robots is a microcosm of more general failures in innovation and investment. On the whole, it is clear that the failure to use robots (and other advanced productive technologies) has undermined Canada's presence in crucial global technology industries, with negative implications for both the quantity and quality of work in Canada. The problem is not that robots are displacing workers from jobs in large numbers (although particular industries and occupations can be disrupted by new technologies). The bigger problem is that Canada isn't using enough robots — and using them well, to build high-value global industries.

III. The Impacts of Technological Stagnation for Canadian Workers

IT IS IRONIC THAT PUBLIC CONCERN ABOUT THE disemployment effects of automation and robotization has coincided with unprecedented weakness in the actual pace of Canadian business investment in new technology (as documented above). Today, facing widespread insecurity and underemployment, many Canadians see automation as just one more reason to worry about the future of their jobs and economic well-being. This is doubly unfortunate. First, it foregoes the potential benefits (higher wages, safer jobs, more leisure time) that could be supported by automation — if the process was managed correctly and fairly. Second, it misdiagnoses the source of the insecurity and hardship currently faced by many workers today. The erosion of stable, decent work in Canada cannot be attributed to automation and mechanization. Those trends have slowed down, not sped up. Instead, the problems facing Canadian workers mostly reflect other factors: including labour and economic policies over recent decades that undermined job security, reduced unionization and collective bargaining, and facilitated the growth of insecure jobs (including part-time jobs, temporary work, and gigs). Those jobs do not generally use robots – or much other advanced technology, for that matter (with the exception of the smart phones that tell gig workers where to pick up their next passenger or food order). But they don't pay very well, or offer opportunity for gratifying, prosperous work, either.

This section of the report will review the impacts of Canada's technological slowdown on work and workers: including the quantity of jobs, their quality, the skills required for work, and the productivity of work. On the whole, the technological slowdown has undermined the jobs and livelihoods of Canadian workers. They would likely be better off if the robots were indeed coming for their jobs.

No Signs of Technological Unemployment

Pessimistic predictions about the impact of automation and other new technologies on overall employment levels are not supported by evidence regarding Canada's labour market performance in recent years. Until the COVID-19 pandemic, the unemployment rate in Canada was trending lower. Indeed, by 2019 average unemployment fell to 5.7% — the lowest since the advent of Statistics Canada's modern labour force data (in 1976). Health restrictions implemented during the pandemic caused a dramatic but temporary increase in unemployment, which peaked at over 13% in May 2020. But employment then recovered quickly — much faster than in earlier recessions (such as the early 1980s and early 1990s). As the economy reopened (interrupted by subsequent COVID waves), the unemployment rate fell quickly. By March 2022 it was down to 5.3%: lower than before the pandemic started.

A lower unemployment rate in itself does not confirm that labour markets are robust: for example, official unemployment could decline because non-employed individuals give up seeking work, which is evidence of disengagement, not vitality. However, in Canada's case, the decline in unemployment over the last two decades reflects a genuine strengthening of labour market conditions, confirmed by other measures such as labour force participation and the employment rate. Labour force participation among the core working age population has increased in recent years — especially among women. And the employment rate (which measures the proportion of working-age people in active employment[23]) has remained strong. Indeed, for the so-called 'core age' workforce (aged 25 to 54), by March 2022 the employment rate reached its highest level ever (almost 85%). So by any measure, the quantity of jobs in Canada's labour market has been healthy – robots or no robots. (The quality of work is more concerning, considered further below.)

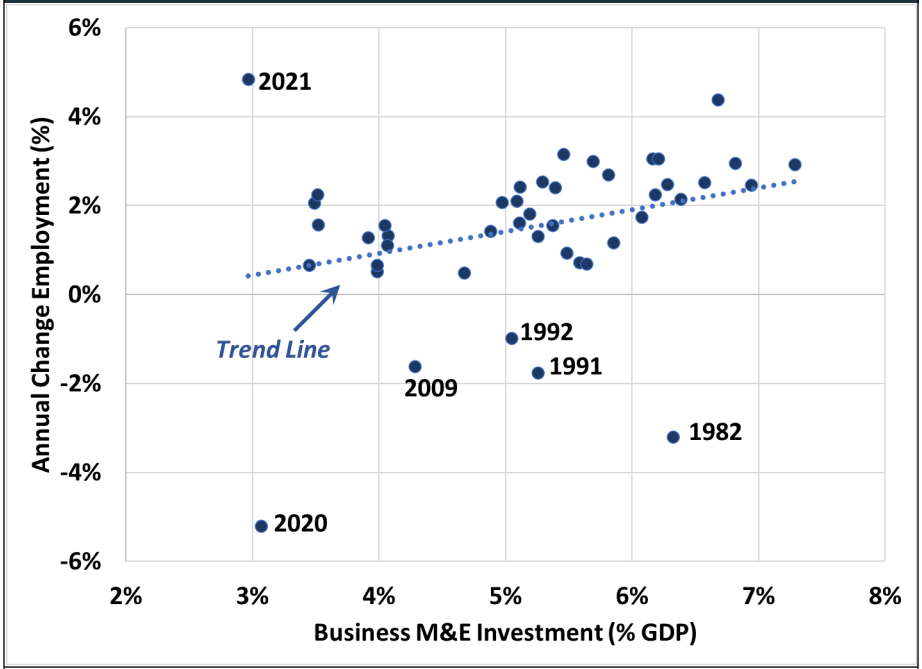
There are many factors contributing to this strong employment growth in Canada in recent years. Monetary policy has become more accommodating in the wake of the painful (and ultimately unnecessary) episodes of deliberate disinflation in the 1980s and 1990s – which was the main cause of poor labour market performance in those decades. Women's increasing labour force participation has also helped to boost overall employment, in both absolute terms and as a proportion of the working age population. Government fiscal policy also changed course: harsh cutbacks in federal and provincial program spending in the 1990s were reversed more recently, and public sector spending and employment have grown. New spending injections were especially important in supporting a fast recovery from the COVID-19 downturn. Canadian job-creation performance could certainly improve further, and the unemployment rate fall lower, if governments adopted more ambitious job-creation, industry-building, and macroeconomic policies. But there is no evidence of the sort of mass technology-induced displacement from employment feared by more pessimistic interpretations.

[23] The employment rate is often considered a more accurate measure of labour market conditions than official unemployment data, since it is unaffected by the potentially arbitrary distinction between unemployed workers and those not in the labour force.

Regarding the specific employment impacts of robots and other modern production technology, business M&E investment has contradictory effects on the quantity of jobs. At the point of direct production, labour-replacing or automated technology may reduce the demand for labour. This is likely offset (at least in part) by new jobs associated with the operation and maintenance of that new technology. Economy-wide employment impacts will also be shaped by new indirect work associated with the development and production of that machinery, and spin-off jobs in new industries opened up by the advent of new technologies. Business investment (including on machinery) also plays an important macroeconomic role in initiating production and generating aggregate spending power, which is also positive for employment. Across all of these diverse effects, it is likely that stronger business M&E investment is a net positive for employment, despite reductions or reallocations in labour demand that may be experienced in specific workplaces or occupations. If anything, therefore, the weakness in Canadian business innovation and investment trends described above has probably had a negative influence on the quantity of available employment.

Figure 11.

Business Machinery Investment and Job Creation, 1976 to 2020



Source: Author's calculations from Statistics Canada Tables 14-10-0327-01 and 36-10-0104-01.

This conclusion is consistent with aggregate economic experience in Canada over the past several decades. Figure 11 compares the rate of business investment in new machinery (measured along the horizontal axis) with the pace of job-creation in the overall economy. There is a reasonably consistent but modest positive association be-

tween business M&E spending and employment growth, represented by the linear trend line.[24] Outlier observations in Figure 11 (data points located far from the trend line) correspond to recessions, when employment declined for other reasons. The worst of these was 2020, when annual average employment fell 5% due to the COVID pandemic, followed by an almost-equal rebound in 2021 (even though M&E investment was still weak).

Far from causing widespread unemployment and dislocation, therefore, in Canadian history stronger business investment in machinery (including robots) has been associated with stronger employment growth. The net effect is small, and there are many other factors (including general macroeconomic conditions) that determine the pace of job-creation. But the common association made between automation and disemployment is not supported by the statistical evidence.

Global comparisons, too, seem to indicate that faster technological change (including robotization) contributes to better labour market performance, not mass displacement. By enhancing competitiveness in international trade, facilitating improved productivity (providing a basis for higher wages), and facilitating the acquisition of advanced skills, stronger innovation and M&E investment are broadly associated with stronger labour market outcomes — including lower unemployment and faster real wage growth.

Table 3 lists Canada, along with the 10 countries with the highest intensity of industrial robot use in the world (according to the International Robotics Federation data, illustrated in Figure 10 above). The table shows robot intensity, overall M&E investment rates (relative to GDP), and average unemployment rates experienced over the last decade. The superior innovation performance of leading technology-adopters like Korea, Japan, and Germany has supported stronger labour market outcomes in those countries, which have recorded significantly lower unemployment than Canada. Indeed, Canada reports the weakest technological performance of any of the countries on Table 3 (by both robot use and broader M&E investment), yet endured the second-highest average unemployment rate (surpassed only fractionally by Sweden). Korea and Hong Kong both invested twice as much of their GDP in new machinery and equipment as Canada, yet experienced average unemployment less than half as high.[25] These international comparisons further refute the assumption that greater use of robots will result in mass displacement of workers and technological unemployment.

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[24] The coefficient on that trend line linking job-creation to M&E investment is statistically significant, and explains about one-fifth of changes in job-creation over this period.

[25] No data on M&E spending in China is available, but almost certainly China's M&E investment share is the highest of any of the countries listed in Table 3. Gross fixed capital formation (including structures) totaled 44.3% of total GDP in China over the 2010-18 period (author's calculations from National Bureau of Statistics of China data), far higher than other countries. M&E spending likely constituted between one-quarter and one-third of that total (or between 10-15% of GDP); that would represent a share of GDP three times larger than in Canada.

Table 3.

Robots, Machines, and Unemployment: Selected Countries

	Robots per 10,000 Manufacturing Workers (2020)	Business M&E Investmt. as %GDP (2010-20 avg.)	Average Unemployment Rate (2010-20, %)
Korea	932	9.0%	3.6%
Singapore	605	5.4%	2.1%
Japan	390	7.8%	3.5%
Germany	371	6.8%	4.7%
Sweden	289	7.2%	7.5%
Hong Kong	275	9.8%	3.6%
U.S.	255	6.7%	6.4%
Taiwan	248	7.8%	4.1%
Denmark	246	5.7%	6.5%
China	246	na	4.6%[1]
Canada	176	4.3%	7.2%

Source: International Federation of Robotics, OECD Employment and Labour Market Statistics, OECD National Accounts Statistics, national statistical sources.

1. Official Chinese labour force data is believed to understate true unemployment there.

In sum, this evidence suggests that fears of widespread job loss arising from the advent of new technologies are misplaced. On balance, new investment in technology is modestly positive for employment. Of course, many other factors (including demographic change and participation trends, fiscal and monetary policy, and export performance) also influence employment outcomes. And while the overall level of employment may not be undermined in a general sense by ongoing technological advancement, displacement and disruption may occur within specific workplaces, industries, and occupations. Those effects can be severe. However, while it is important to pay appropriate attention to these adjustments, and ensure that workers have adequate input and protections as technological change occurs,[26] it seems that faster investment in automation and mechanization have generally positive net impacts on the quantity of employment.

[26] See Stanford and Bennett (2021) for discussion of specific measures and policies which facilitate collective input by workers into the implementation of new technology in Canadian workplaces.

Job Creation in Low-Tech Sectors

While the overall quantity of work in Canada's economy has not been significantly undermined by the introduction of labour-saving technologies (and in fact would probably have performed better with stronger technology adoption here), Canada's flagging innovation performance has implications for the *composition* of future employment. The assumption is often made that the best future job opportunities will be opened up in technology-intensive industries and occupations — such as programming, engineering, and other high-tech fields. For individuals, the obvious advice is to learn coding and other tech skills to enhance one's success in the future labour market. For the broader economy, the policy implication is to focus on providing more training and retraining opportunities (with a focus on technology-intensive fields) as a way of lubricating the labour market's coming transition toward high-tech vocations.

It turns out that these assumptions that high-tech industries will be the source of most future new work are also misplaced. In fact, technology-intensive sectors and occupations have accounted for a small share of total new work in recent years — and that trend is likely to continue. The slow pace of Canadian innovation and technology adoption helps explain the surprisingly small number of tech jobs being created. But even if our technology performance were stronger, the fundamental structure of the economy would still require that most new work will be created in other sectors and occupations. Technology-intensive industries and occupations, even though growing rapidly, constitute a small share of total jobs. Other, larger sectors — including many relatively low-tech and lower quality jobs — account for most job creation. In this context, perhaps more emphasis should be placed on lifting the quality of jobs created in those less tech-centric vocations, rather than focusing so narrowly on encouraging workers to learn the latest tech skills as the best path to prosperity.

Table 4 reports the growth of payroll employment[27] in Canada by broad sector in the 5 years ending in 2019 – before employment patterns were dramatically (but temporarily) disrupted by the COVID-19 pandemic. Employment growth is expressed in both absolute and percentage terms; the sectors are ranked according to the greatest absolute number of new jobs created in that period. Table 5 includes 19 major sectors defined by Statistics Canada at the 2-digit level. Of course, some technology-intensive jobs exist within any of those sectors. But we have identified 6 sub-sectors with an especially strong focus on new technologies, and combined them in a "tech cluster" that is also reported on Table 4.

[27] Payroll employment statistics exclude self-employment.

Table 4.

Job-Creation by Industry, 2014-2019

Sector	Absolute Growth Employment (000s)	Percent Growth Employment (%)
Health care and social assistance	260.7	14.6%
Accommodation and food services	140.8	11.7%
Educational services	138.5	11.4%
Professional, scientific and technical services	132.0	15.7%
Public administration	102.5	9.8%
***TECH CLUSTER*[1]**	90.7	18.0%
Manufacturing	87.7	5.9%
Retail trade	67.6	3.5%
Transportation and warehousing	66.9	9.4%
Construction	65.9	6.8%
Administrative and support services	60.2	7.7%
Arts, entertainment and recreation	56.8	22.2%
Finance and insurance	44.9	6.4%
Wholesale trade	42.5	5.4%
Real estate and rental and leasing	16.7	5.9%
Information and cultural industries	10.4	3.0%
Other services	10.4	1.9%
Utilities	10.4	8.9%
Forestry	0.0	-0.1%
Mining and petroleum	-31.4	-13.5%
TOTAL[2]	**1,287.7**	**8.4%**

Source: Author's calculations from Statistics Canada Table 14-10-0201-01.

1. Includes 6 sub-sectors: computer system design and services; telecommunications; data processing; scientific and technical consulting; scientific R&D services; and other information services.

2. Does not include employment in the identified 'tech cluster' since those sub-sectors are also included in other broad sector categories.

Over those five years, in the context of relatively strong labour market performance, some 1.3 million new jobs were created in Canada, representing an 8.4% increase in payroll employment. The health care and social services sector was by far the most important source of new work in this period, adding 260,000 new jobs, or about one-fifth of the total. Health care employment grew at a robust rate of almost 3% per year. Two other large public sector industries — education and public administration — added another 240,000 jobs in this period. Together, the public sector added one-half million jobs during those five years.

Job-creation in those public, human, and caring service activities swamped the expansion of employment in high-tech industries. Our set of six technology-intensive sub-sectors added a total 90,000 jobs in five years. The rate of employment expansion was faster (18%, versus 10-15% in the public sector industries). But the sheer number of new jobs was much smaller in the high-tech cluster — simply because it constitutes a relatively small and specialized segment of the overall labour market.

Other major sources of new work in this period included hospitality (the second-largest source of new jobs, after health care), manufacturing, retail trade, transportation, and construction. Those rather more traditional private sector industries added far more new work, in total, than the cluster of high-tech industries.[28] Resource-based industries (including mining, petroleum, and forestry) lost jobs over this period.

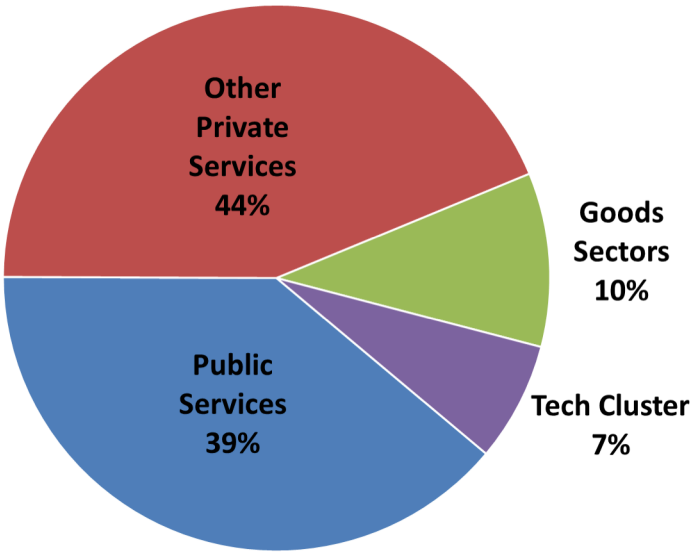
Figure 12 illustrates the relatively small role of high-tech industries in overall job-creation in Canada in recent years. The cluster of six high-tech sub-sectors defined above accounted for just 7% of the 1.3 million jobs produced in Canada over that period. Public services and other private service sectors accounted for the lion's share of total new work. Goods producing industries (mostly manufacturing) made up the remaining 10% of new work. Private services jobs range widely in quality, security, and compensation. Many of the new jobs in private services are in sectors (including hospitality and retail trade) characterized by part-time, low-wage, and insecure work. Public sector jobs, in contrast, tend to be more stable and somewhat better-paying (reflecting higher education levels, greater union influence, and government fair employment policies).

This decomposition of job-creation in Canada by industry grouping likely understates the importance of high-tech work in the evolving labour market, because technology-intensive occupations are found in all parts of the economy — not just in focused high-tech sub-sectors. An alternative view on the technological characteristics of new jobs can be obtained by decomposing new employment growth by occupation, rather than by industry. This approach, too, is imperfect, since Statistics Canada's occupational categories tend to overlap with sector definitions. For example, the agency reports broad occupational groupings that correspond with health,

[28] The 2-digit category listed in Table 4 for professional and scientific services added 132,000 jobs over the five years, but most of those were within 3 of the sub-sectors that are included in our 'tech cluster'; excluding those tech-focused sub-sectors, the remaining segments of professional and technical services created about 45,000 jobs.

Figure 12.

Job-Creation by Industry Category



Source: Author's calculations from Statistics Canada Table 14-10-0201-01.

education, manufacturing, and resources — largely duplicating information gleaned from the sectoral decomposition reported above. Nevertheless, the occupational data provide some additional detail on the composition of new work in Canada. And this analysis confirms that scientific and technical occupations account for a surprisingly small portion of new work. Much more new work has been created in public services and other, lower-tech private service occupations.

Table 5 reports the composition of total job growth in Canada over the same five-year period leading up to the COVID-19 pandemic. This data is based on Statistics Canada's Labour Force Survey of households, and hence includes self-employment. Total employment growth by this measure roughly matches that reported in the payroll data summarized in Table 4: the economy created 1.3 million new jobs over the five years.[29] In this case, occupations in natural and physical sciences (both professional and technical occupations) rank as the largest single source of new work: with 211,000 new positions added (about one-sixth of the total). Health-related occupations added almost as many new jobs — and demonstrated a slightly faster rate of growth (up 17%). Jobs in sales and service (including the large retail and hospitality sectors) also expanded rapidly, followed by business, and education and other public

[29] The cumulative percentage growth (7.4%) is smaller in Table 5 than Table 4 (8.4%) because the labour force data includes self-employment (which was largely stagnant over this period). The same absolute job growth applied against a larger starting point results in a smaller proportional growth.

Table 5.

Job-Creation by Occupation, 2014-2019

Occupation	Absolute Growth Employment (000s)	Percent Growth Employment (%)
Sciences	211.0	15.7%
Health	208.2	17.1%
Sales & Service	192.1	4.4%
Business	191.1	6.7%
Education, Law & Other Public	176.3	9.1%
Trades & Transport	165.2	6.4%
Management	129.4	8.1%
Manufacturing & Utilities	24.4	2.9%
Culture & Recreation	20.4	3.8%
Resources	-9.6	-2.5%
TOTAL[2]	**1,308.5**	**7.4%**

Source: Author's calculations from Statistics Canada Table 14-10-0296-01.

service occupations. Once again, the occupational employment disaggregation indicates that high-tech work has been growing rapidly — but constitutes a minority of new jobs. Instead, public service professions, and a wide range of other private service sector work (much of which is relatively low-paid and insecure), have been the more important sources of new jobs.

Projections of future employment growth by occupation (based on forecasts from industry, government, and post-secondary educational institutions) suggest that this broad pattern of new job creation is likely to be maintained in the future. Table 6 reports official occupational growth forecasts from the federal government's Canadian Occupational Projection System. The twelve largest occupational sources of job-creation are listed in the table. It is striking that six of those occupations (accounting for 60% of total new jobs from these leading dozen occupations) are in public service occupations: health care, education, and social services. Four relatively low-wage low-tech private service occupations account for another quarter of the new jobs in those twelve sectors. Just two of the occupations listed (ICT analysts and computer programmers) represent technology-intensive roles as conventionally understood; they account for just 15% of total new jobs across those leading occupations.

Table 6.

Sources of Future Job-Creation, 2018-2028

Occupation	New Jobs (000)	Occupation	New Jobs (000)
Nurses	102.8	ECE educators & assistants	30.2
Nursing aides & orderlies	92.9	Computer programmers & media designers	32.1
ICT analysts & consultants	52.7	Light duty cleaners	29.7
Food attendants & helpers	46.2	Transport truck drivers	29.5
Social & community	38.7	GPs & Physicians	28.2
Elementary & kindergarten teachers	33.1	Cashiers	27.2

Source: Author's calculations from Employment and Social Development Canada (2021).

Whether we consider recent history, therefore, or look into the future, the importance of high-technology jobs in Canada's overall labour market performance has been overstated. Those technology-intensive occupations are certainly growing rapidly, and employers in those sectors confront ongoing challenges to recruit and retain skilled workers. But in the grand scheme of the broader labour market, those high-tech industries and occupations play a relatively small role. To some extent this reflects the failure of Canada's economy to nurture a sustained and dynamic business culture, with appropriate emphasis on innovation and adoption of new technologies (as documented in the preceding section). But to some extent it also reflects a deeper, more fundamental fact of economic life: the simple reality is that most work in our economy, and most new jobs in the future, will not consist of high-tech vocations. Most new work, instead, will be created in occupations which perform services for other Canadians: human and caring services funded mostly through government, and private service functions (many with inferior conditions and compensation) delivered through competitive private markets. Trying to strengthen Canada's technological performance is important in trying to improve the composition of future job growth, to be sure. But that must be complemented by strong efforts to improve the quality and stability of jobs in the service occupations which in any event will constitute the majority of new work in the future. The quality of these service-sector jobs can be lifted by enhancing fiscal support for public service delivery, and improving working conditions and labour standards in private service jobs.

Underutilization of Skills

A common response to the concern that new technologies may displace large segments of the workforce is to urge workers to acquire additional training — preferably with a focus on computer-related skills (like coding or networks). The adoption of new technology in Canada has been slower than common discourse would expect, and there is no empirical evidence of mass technological displacement of workers. Nevertheless, investing in more skills and education is a positive goal, from both an individual and a social perspective. However, investments in the skills and capabilities of our future workforce should be complemented by a parallel commitment to ensuring those skills are put to work in real jobs. Policy-makers need to pay attention to creating higher-quality, technology-intensive employment opportunities so that those acquired skills are applied in practice.

By some measures, Canadian workers are already the best-trained in the world. As illustrated in Figure 13, the proportion of the core-age (25-64) Canadian workforce with tertiary education is the highest in the OECD: almost 60% of workers in 2020 had some post-secondary training. It is hard to argue that Canada's technological development is held back by shortages of skills — although in certain specialized occupations, to be sure, trained talent is scarce.

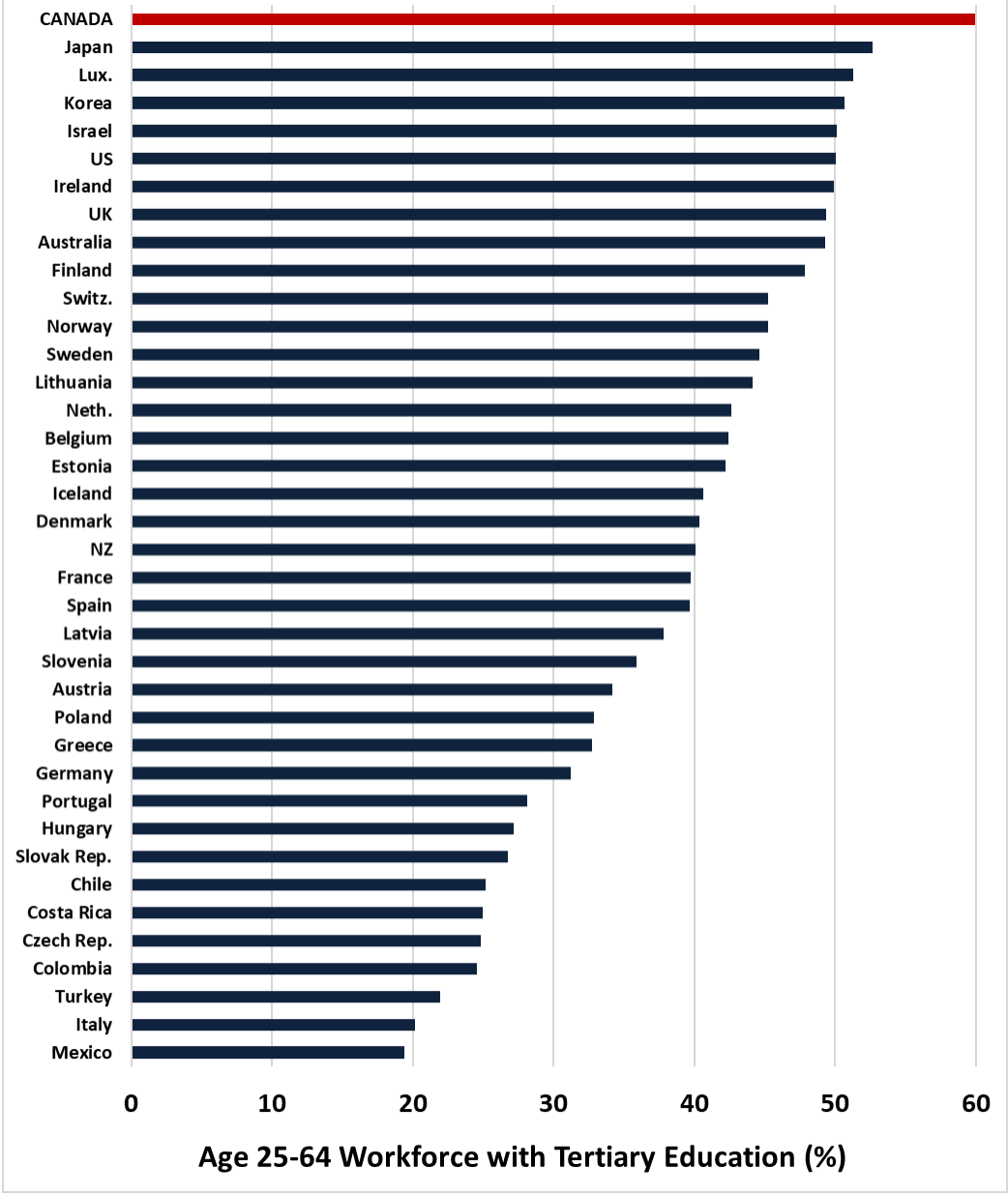
Instead, a more worrisome indicator — in part a consequence of Canada's technological slowdown — is the *underutilization* of skills which Canadians have already acquired. Statistics Canada reports that 31% (almost one-third) of all 25-64 year old workers with a university degree were employed in jobs that did not require that degree (LaRochelle-Côté and Hango, 2016). Underutilization of skills is worse among younger university graduates (under 35), 40% of whom worked in jobs which did not require their degree, and among immigrants (Uppal and LaRochelle-Côté, 2014). Indeed, 43% of university graduate women immigrants, and 35% of men, worked in jobs that required just high school (Uppal and LaRochelle-Côté, 2014). The economic cost of this underutilization, especially among immigrants, has been estimated at close to $20 billion per year (McCann et al., 2019). Other consequences of underemployment and underutilization of skills include higher job dissatisfaction among workers whose skills are not used in their work, and resulting elevated levels of job turnover.

The conventional advice that workers can position themselves for success in a rapidly advancing high-tech economy by simply learning the right skills is thus thrown into question for multiple reasons. As we have seen, from a macroeconomic perspective there is little evidence that automation, mechanization, and innovation are genuinely accelerating. A large share of new jobs being created in the economy do not require advanced training and education. And Canadian workers are already highly-educated — yet millions do not have the opportunity to use their hard-earned (and expensive) skills at work. Investing in more skills (especially if accompanied by stronger pathways for newly-trained workers to find relevant and challenging jobs) can play a vital role in a successful technology strategy for the economy. But in this context, the conventional single-minded focus on skills and training as the avenue to future job mar-

ket success (both individually and economy-wide) must be considered with caution. Skills and training are important, but just one part of the solution. The economy also needs much stronger investment in innovation and technology, efforts to expand industries which use that new technology, and active policies to lift the quality of work – in every sector.

Figure 13.

Tertiary Education, OECD Countries, 2020



Source: OECD Education Statistics.

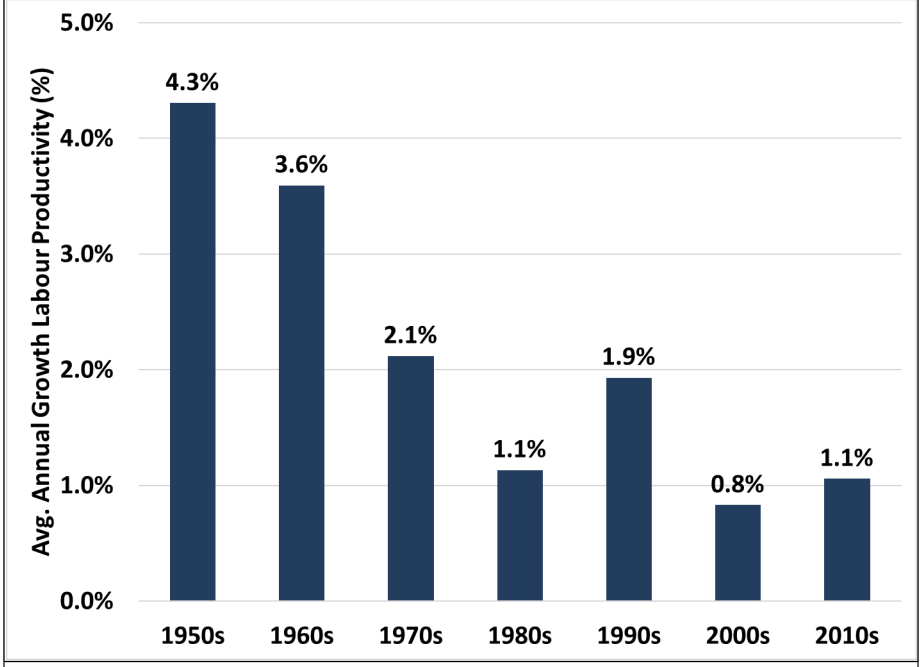
Disappointing Productivity Growth

One additional implication of the slowdown in Canadian innovation, investment, and mechanization is Canada's chronically disappointing productivity growth. Labour productivity measures the real value-added output produced by a typical worker in a given period of time (per hour or per year). The growth of labour productivity over time is a fundamental sign of economic development. It creates the economic foundation for improved living standards — though whether it translates into mass prosperity depends on institutions and policies to ensure that improved productivity is broadly shared. Productivity depends on many different factors, but one of the most important is the technology and tools which workers use in their labour. Workers cannot do much with their bare hands. But if they use sophisticated technology and machinery in the course of their work, productivity will increase.

If automation and mechanization were truly having widespread labour-replacing effects (whereby greater use of machines leads to reduced demand for labour in production), then labour productivity would unambiguously accelerate. The same or greater output produced with fewer workers implies increases in productivity. Once again, however, empirical evidence confirms this is not occurring. To the contrary, as illustrated in Figure 14, labour productivity growth has slowed since the turn of the century. This corresponds to the marked slowdown in business innovation and technology spending during the same period that was described earlier.

Figure 14.

Labour Productivity Growth, 1950-2019



Source: Author's calculations from Statistics Canada Tables 36-10-0305-01 and 36-10-0206-01. 2010s average measured to 2019 to exclude impact of COVID pandemic.

During the initial postwar expansion, labour productivity in Canada grew at a robust pace: by an average of 3.5% per year between 1950 and 1980. This provided a real underpinning for sustained increases in wages and living standards that were enjoyed in the postwar era: indeed, real incomes roughly doubled over that period. Of course, higher labour productivity alone does not guarantee that workers receive higher wages. This requires institutional and regulatory measures to ensure that workers win wages that reflect the improved efficiency of their labour. Canada's economy in the postwar era did indeed promote broad (although not universal) inclusion in economic prosperity: with measures like higher minimum wages, trade unions, and a growing network of public and social programs (which supplemented private market incomes with a growing "social wage"). All those equality-enhancing measures were just as important to rising living standards as the strong pace of productivity growth. In other words, productivity growth is a necessary but not sufficient condition for mass prosperity. And Canada's productivity performance in those earlier decades was very strong: productivity increased rapidly, largely closing the traditional gap with the U.S. and other industrial countries.

Productivity growth then weakened during the 1980s (as Canada's economy grappled with recession and contractionary monetary and fiscal policies), but recovered somewhat in the 1990s (regaining a 2% annual average pace). Since the turn of the century, however, labour productivity growth has slowed significantly. During the 2000s, when Canada's energy boom took off in earnest, productivity growth fell below 1% per year: one-third the pace recorded in the earlier postwar decades. It rebounded only slightly during the 2010s. During the COVID-19 pandemic, average labour productivity declined in outright terms (as a result of "labour hoarding," whereby employers — supported by government wage subsidies — temporarily kept more workers on their payrolls than they needed given sales levels). Productivity recovered somewhat in 2021 with the re-opening of the economy, but there is no indication that the longer-term stagnation of productivity visible since the turn of the century has been repaired.

Several factors account for the slowdown in real productivity growth in Canada's economy since 2000:

- The failure of Canadian businesses to adequately invest in new technologies and ideas, and to put those ideas into practice through investments in tangible machinery and capital.

- The growing importance of resource extraction (especially petroleum). Resource industries produce high levels of output per worker, but productivity declines over time (as more easily-extracted reserves of minerals are exhausted, and more inaccessible and expensive resources are exploited).

- The growth of low-tech private service industries (such as hospitality and retail), which have very low levels of labour productivity – but which account for a significant proportion of new jobs (as described above).

- The erosion of previously strong labour standards and workplace protections, allowing employers to profitably employ labour in relatively low-productivity, insecure, poorly-paid jobs.

The evidence above suggests that weak productivity performance is closely correlated with the failure of Canadian businesses to adequately invest in innovation and capital equipment. The productivity slowdown contradicts the expectation that labour is being replaced by machines to any widespread extent. If that were true, productivity growth would be accelerating, by definition, and the capital-labour ratio would unequivocally grow. This is clearly not happening. But that doesn't mean workers are better off. The weakness of innovation and technology investment, and the resulting slow pace of productivity growth, will exacerbate distributional struggles and undermine future real wage growth. It also damages the international competitiveness of Canadian products, and is associated with the continuing shift of employment toward low-tech, poorly-paid jobs (especially in private service industries). Fears about mass technological displacement of workers by robots are clearly not justified by empirical evidence of Canada's recent economic performance. But the absence of automation has likely contributed to (and at minimum is strongly associated with) the evident deterioration in the quality and productivity of so many jobs.

Productivity growth does not guarantee improvements in living standards for the bulk of the population: that requires workers to have enough institutional support and bargaining power, to capture a fair share of higher productivity in the form of higher real incomes and/or shorter working hours. But productivity growth creates economic space for those improvements to be won. And the slowdown in productivity growth in Canada since the turn of the century reflects deeper issues in our innovation and investment ecology — with negative consequences for Canadian workers.

IV. Implications for Policy

THE PRECEDING ANALYSIS PROVIDES A COUNTER-NARRATIVE TO the common conception that the future of work will be dictated by the onward rush of technology. To be sure, robots (and other advanced technologies) can do incredible things, especially in controlled settings. But their ultimate and widespread application in the real-world economy depends on many other factors: including the sectoral composition of the economy; the talent, ambition and capacity of business leadership; broader macroeconomic trends; the skills and capacities of workers; regulations and infrastructure; and global economic conditions. For these and other reasons, Canadian businesses are failing to put the full potential of new technologies (including robotics, automation, and artificial intelligence) into motion. This section of the report will review the impacts of Canada's technological slowdown on work and workers: including the quantity of jobs, their quality, the skills required for work, and the productivity of work. On the whole, the technological slowdown has undermined the jobs and livelihoods of Canadian workers. They would likely be better off if the robots were indeed coming for their jobs.

The end result is an economy that, by some measures, has stopped advancing, and may even be going backward. That surprising qualitative regression was visible before the COVID-19 pandemic. But the pandemic has exacerbated the weakness of business investment and innovation in Canada, and caused our economy to slip further behind other countries in the pace of innovation. Capital-intensity is declining, rather than increasing. A growing share of Canadians is employed in relatively menial, low-tech, poorly-paid and often-insecure jobs: in sectors like retail, hospitality, and personal services. The dystopian vision of mass technology-induced unemployment is certainly not coming true. But what we are getting instead is equally discouraging.

A common element behind the worrisome trends described above is the failure of Canadian businesses to invest adequately in new ideas and new technologies: pure innovation, tangible assets like machinery and equipment (including robots), and broader capital accumulation. Hence, a comprehensive policy response to these issues must focus on measures to boost the pace of innovation here, to apply new ideas and technologies more ambitiously in the real economy, to equip Canadian workers to perform new functions — and then empower them to win a fair share of the resulting economic gains. Here are several broad policy implications suggested by the preceding analysis:

Focus Fiscal Support on Investment and Adoption

There is no wave of all-knowing machines penetrating Canada's economy, displacing human workers and creating massive adjustment and unemployment problems. To the contrary, technical progress across the real economy was significantly faster in the latter half of the twentieth century, than it has been more recently. Over the last decade the pace of investment in new machinery and equipment (including robots) in Canada has been positively glacial.

Traditional business-friendly measures like deregulation, across-the-board tax cuts, tax preferences for certain kinds of investment (such as mining and property development), outsourcing and privatization of public services, and other measures to enhance business freedom and proftability have not stopped the decline in innovation and technology investment. Indeed, some of these measures may have discouraged investments in genuinely innovative products and processes. For example, efforts to reduce labour costs (by relaxing labour standards, facilitating deunionization, and liberalizing precarious employment arrangements) reduces the incentive for firms to invest in labour-saving technologies — since it becomes more viable to hire labour in low-wage, low-productivity functions.

Of particular relevance here is the failure of across-the-board company tax reductions to elicit a stronger investment effort from Canadian firms. Since the turn of the century, the federal and most provincial governments implemented significant reductions in company tax rates. This approach was justified with arguments that lower taxes would stimulate business capital spending of all kinds — especially innovation and technology. However, the persistent weakness in innovation investment since then suggests that across-the-board tax cuts, with no conditions attached regarding reinvestment of resulting savings, had little if any impact on the investment effort of Canadian businesses. There are other, more promising policy fiscal options for eliciting more real investment effort from Canada's business sector, instead of this business-friendly, 'trickle-down' approach.

For example, fiscal measures would have more effect on investment spending if they were tied directly to incremental investment decisions. Measures like accelerated depreciation for capital investment or investment tax credits would be more effective in eliciting new commitments to incremental investments. Those measures can be tailoured to provide maximum incentive for investment in particular strategic assets —

such as advanced machinery and equipment, robots, and other cutting-edge technologies.

In many cases, direct participation by public agencies could motivate and accelerate investment in desired sectors and technologies. Partnerships of public and private capital could be effective in motivating more tangible capital investment in targeted sectors. An example of this approach is the co-investment strategy adopted by federal and provincial governments in leveraging important investments in the automotive, aerospace, and renewable technology industries.

More direct public participation would also help to encourage a stronger R&D effort by business. To date, Canada has relied mostly on tax incentives to support private R&D; Canada's R&D tax policies are among the most favourable in the industrial world. In the 2010s, R&D tax credits amounted to 16.5% of all business R&D spending in Canada – three times the OECD average.[30] In contrast, direct government participation in business R&D projects has been relatively weak: half as much, relative to GDP, as the average for other OECD countries. International evidence suggests that countries which invest public support more directly in targeted innovation projects (or "missions," to use the terminology of Mazzucato, 2021) ultimately elicit more private innovation spending than tax incentives. There are many upcoming technologies and projects for which direct public participation would be appropriate and effective in motivating more overall innovation investment (both tangible and intangible): such as major investments in renewable energy technologies (including electric vehicles), medical and pharmaceutical technologies, and high-tech public service investments (such as specialized health care facilities).

Nurture Industries that Use Robots (and Other New Technology)

An important factor in the secular decline of Canadian innovation activity has been the contraction of industries that use those technologies intensively in their own production. In particular, the erosion of domestic manufacturing since the turn of the century has damaged Canadian technology investment. Manufacturing is the most innovation-intensive sector in the economy: manufacturers invest a larger share of total output back into new R&D than any other part of the economy, and employ the most automated machinery and other new tangible technology in their operations. A country with a larger manufacturing base will have greater capacity to conduct R&D and other innovation, and more opportunities to apply new technologies in practical, shop-floor settings.

Moreover, a sophisticated and technologically adept manufacturing sector contributes to innovation and mechanization in the rest of the economy, too: since robots and other advanced machinery are, in and of themselves, manufactured products, having adjacent manufacturing capabilities can support businesses in any sector (including resources, agriculture, and services) to successfully apply automated technologies in their own businesses.

[30] Author's calculations from OECD, R&D Tax Expenditure and Direct Government Funding of BERD.

The automotive assembly industry is among the most intensive users of robotics in the world; the erosion of Canadian automotive manufacturing since the turn of the century has thus contributed to our weak performance in applying automated technologies. Other strategic sectors which are key users of automation and other advanced machinery include aerospace, electronics, and medical and pharmaceutical manufacturing. In all of these cases, Canada had previously carved out important footholds in global supply chains — and this strong presence in technology-intensive global industries was a key factor in Canada's relatively strong technological performance in the second half of the twentieth century, as we gradually closed the gap with the rest of the industrial world. Since 2000, however, alongside the boom in resource extraction and the signing of major free trade agreements, active efforts to nurture these strategic high-tech industries receded. The result has been a general process of deindustrialization that has contributed to the slowdown of Canadian innovation activity.

Rather than assuming that free market forces alone (cemented by tax cuts, trade deals, and a laissez faire approach to industrial structure) will guide the national economy toward an optimal sectoral composition, more economists now recognize that targeted industrial or sector development policies are beneficial in attracting and expanding desirable technology-intensive industries.[31] While active industrial policy-making was traditionally focused on large-scale manufacturing facilities, modern approaches look beyond manufacturing to include other sectors and activities with similar attributes. Any sector that is innovation-and technology-intensive, oriented toward export market opportunities, generates higher-skill and well-paying jobs, demonstrates strong productivity growth, and anchors the presence of domestic supply chains should be a candidate for targeted policy support from governments.[32] Non-manufacturing sectors which make positive strategic contributions in this context include sectors like high-value business services; technology and digital industries; tradeable culture industries; high-value tourism; and specialized public services (like specialized health care and higher education). These types of sectors are as deserving of targeted sectoral development policies as traditional large-scale manufacturing – and they all use advanced technology relatively intensively.

International experience also affirms the value of a more inclusive and collaborative approach by government to fostering economic and technological development, rather than a "hands-off" strategy which leaves major decisions to private sector actors. Countries with more vibrant investment and innovation records, which in turn translate into greater success in international trade and lower unemployment, include those with a multi-partite or corporatist approach to investment, training, and exports. Notable examples of this approach include Germany and other continental European countries, the Nordic countries, and the industrial powerhouses of east Asia (led by Japan and Korea, and now including China, Taiwan, and Singapore).

[31] See Stiglitz et al. (2013), Rodrik (2008), and Mazzucato (2011, 2021) for important statements of this increasingly accepted view.

[32] Stanford (2012) discusses the criteria for appropriate application of industrial and sector development policies in more detail.

If we are to develop and foster a stronger portfolio of technology-intensive industries in Canada, and thus enhance our overall innovation and investment effort accordingly, government needs to play a more active, ambitious role in supporting investment (both tangible and intangible) in targeted sectors. In addition to supporting investment through the concrete fiscal measures described above, this will also require acting to create economic conditions receptive to the success of domestic high-tech producers: including stronger public procurement strategies, meaningful efforts to stimulate exports of value-added products and services (rather than relying so heavily on primary exports), and well-resourced skills and training programs.

Boost Public Innovation Investment

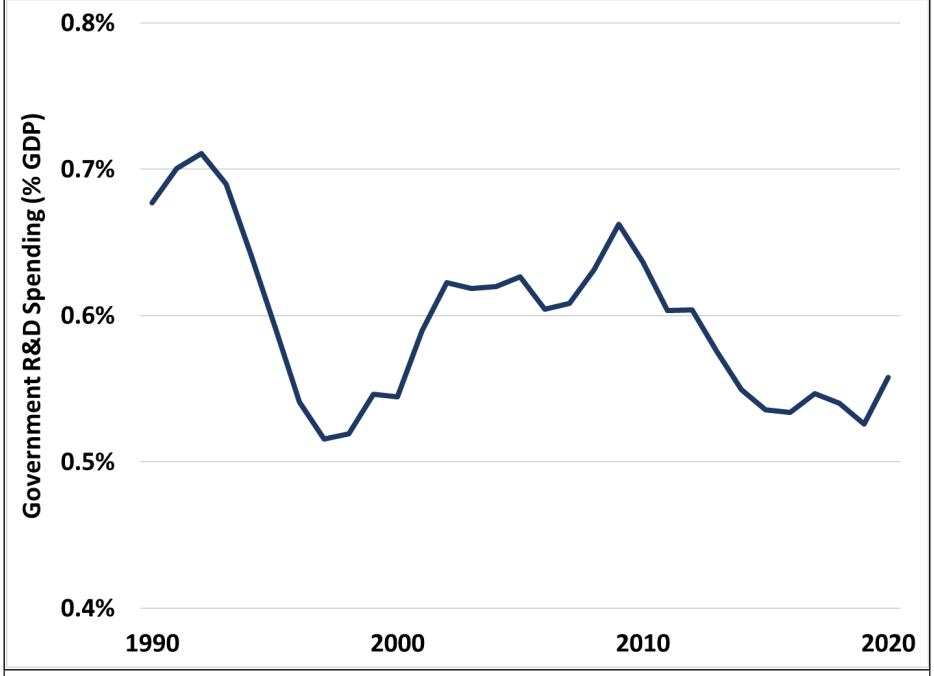
The empirical data presented above focused on the erosion of innovation spending by Canadian businesses: both intangible R&D, and tangible machinery and equipment. But not all progress in the development and use of new technology is driven by the private sector. Government and public agencies also have an important role to play in directly undertaking innovation and technology adoption. That includes financing innovation activity: through direct participation in business R&D projects (discussed above), and government support for research activity in other sectors (including within government departments, in universities, and in other broader public sector institutions). It also includes adoption of modern technology and machinery in public sector operations: including within government itself, and in public sector industries (such as health care and education). By providing opportunities to apply new technologies in real-world settings, early adoption by public sector organizations of new technologies can contribute to ongoing adaptation and improvements in those innovations. Purchases of Canadian-developed technology by governments and public sector agencies can also provide Canadian innovators with needed sales, and signal to other potential consumers (including in export markets) the confidence and esteem with which these innovators are viewed in their home market.

Canadian government fiscal support for R&D — whether conducted within government, by private businesses, or in other institutions like universities — has been inconsistent in recent years (see Figure 15). It declined relative to GDP in the fiscally-constrained 1990s, rebounded in the 2000s, but declined again over the last decade. At 0.56% of GDP in 2020, government R&D funding was about the same as in 2001 — the point at which Canada's overall innovation effort began to weaken considerably. So the downturn in overall R&D activity in Canada (which fell by one-third of a percentage point of GDP over this period) cannot be attributed to shrinkage in government's direct funding. However, government support for innovation has been inconsistent, and ranks slightly below the OECD average. Given Canada's weakness in broader R&D activity (especially emanating from the business sector), a strong case can be made for stepping up government's support for research and innovation.

Canadian governments could also step up their own direct investments in adoption of tangible machinery and technology, including in government and in public sector agencies. No disaggregated data on M&E investments in the public sector is published by Statistics Canada. The overall trend of capital investment by governments

Figure 15.

Government R&D Spending, 1990-2020



Source: OECD Science, Technology and R&D Statistics.

and public agencies showed a substantial weakening in the 1990s. Total fixed capital spending in the public sector fell from an average of 5-6% of Canadian GDP in the 1960s and 1970s, to just 3% in the austere 1990s — when both federal and provincial governments cut back capital spending in the course of their deficit-reduction efforts. Since then, public investment has regained some of that ground, averaging 4% of GDP through the 2010s, and making a more significant contribution to economic growth and job creation since then. However, it is clear that public capital spending is still inadequate given the expanding needs of Canadian communities for quality infrastructure and public facilities.

And in the present context, there should be a stronger emphasis on the technological content of public capital investments. We should see the broader public sector as not only fulfilling the demands of Canadians for basic services. We should also see it as an avenue for advancing the technological capabilities of the whole economy, and the broader workforce. In some other countries (such as the Nordic countries), public services are deliberately managed to incorporate cutting-edge technologies and machinery: not just to provide higher-quality, cost-effective public services, but also to contribute to overall innovative capability across the economy. Canadian governments could do the same, with a pro-active effort to lift the technological content of public services and public infrastructure – and with a special focus on supporting home-grown technology and Canadian-made equipment.

Invest in Skills and Job Pathways

The most common advice for surviving the coming of the robots, at least at the individual level, is for workers to learn new skills to preserve their employability in a high-tech economy. Workers with more training and education — preferably in technical or computer fields — are expected to have their pick of jobs in the brave new automated future. Workers who do not attain these skills will face discouraging employment prospects, left behind by automation and artificial intelligence. For policy-makers, the parallel conclusion is usually that providing additional support for training and re-training will help the labour market to adjust to new technologies.

In contrast to this common advice, it is not obvious that Canada's economy has truly become more skills-intensive. As described above, relatively few jobs are being created in the most technology-intensive industries and occupations. More jobs have been created in relatively low-tech sectors, where innovation has been slow: like retail, hospitality, and personal services. Public and human services have been another hot spot for job-creation; many of those jobs (in health care, education, and other services) are certainly technology- and skills-intensive, but not with a narrow focus on coding and robots. Meanwhile, individuals with higher education have better employment outcomes — but that also reflects the role of credentialization and "degree inflation" in helping better-educated individuals land scarce jobs. It does not prove that their skills are actually required to perform the functions they were hired for (as suggested by the evidence on widespread underutilization of existing credentials presented above).

Therefore, investing in more skills should not be seen as a panacea for improving employment outcomes in a time of technological transition. Strengthening skills programs (especially in vocational education) and improving pathways for skilled graduates into jobs that use their skills can certainly play a role in facilitating the expansion of high-tech industries. But that strategy should be understood as one element in a broader portfolio of policies focused on the overarching goal of stimulating the creation of higher-skill jobs (and the industries that provide them). Merely possessing valuable skills means little if jobs are not available to use them. The evidence above indicates that Canada's poor performance in innovation, and in nurturing industries that use new knowledge and technologies intensely, is the primary constraint on applied technological progress in Canada — not a lack of skilled workers.

Concrete steps that would strengthen the tie between technology-relevant post-secondary education and placement in jobs which actually use those skills would include:

- More resources for colleges and vocational programs, which have been underfunded relative to university education in Canada.

- Stronger job-placement links for students in technology-relevant programs of study, so they can acquire on-the-job experience and industry contacts.

- Better regulation of specific technology-relevant skilled trades, to identify and certify recognized areas of training and capability, ensure well-rounded training and apprenticeship programs, and enhance recognition and portability of those qualifications once achieved.

- Fiscal incentives for employers to invest in job-specific training programs (including apprenticeships), such as training levies which are refunded to employers on the basis of their own training expenditures.

Ensure that Labour is Scarce and Expensive

To some extent, business decisions regarding the use of human labour versus machinery and equipment will reflect management judgments regarding the relative price and availability of each input. If labour is abundant and relatively inexpensive, then the economic incentive for businesses to invest in labour-saving technology is reduced. The "payoff" time for such investments is extended, and operational pressures (such as challenges in recruiting and retaining labour) which might spur managers to invest in machinery are relaxed.

The importance of this factor substitutability should not be overstated. Many technologies have little leeway to substitute capital for labour (or vice versa) on a discretionary basis: the relative inputs of each factor in production are largely fixed by the parameters of technology. In many industries, prescribed machinery is required for production to occur, regardless of the relative prices of capital and labour. The experience of newly industrializing countries (like China) in rapidly adopting new technology (including more robots per capita than Canada) despite more abundant and less expensive labour, is also inconsistent with a strict factor-price theory of technological change. Nevertheless, there is some flexibility in business decisions regarding factor inputs. Thus, if greater adoption of advanced machinery and technology is an economic goal,[33] then reinforcing the financial incentives for employers to invest in labour-saving technology is useful. This implies managing macroeconomic conditions as close to full employment as possible, and supporting (rather than suppressing) real wage growth. If labour is scarce and expensive, employers will be more amenable to investing in labour-saving technology.

[33] In some situations this would not be a goal: for example, in developing economies with large populations of surplus or underutilized labour, it is more important to implement production systems that use labour more intensively (as argued in the "appropriate technology" literature; for example, see Kaplinsky, 2011).

Table 7.

Mechanization, Unemployment, and Wages, 1950-2019

	Business Machinery & Equipment Investment (% GDP)	Unemployment Rate (%)	Average Annual Increase Real Weekly Earnings (%)
1950s	7.1	4.2	3.1
1960s	5.9	5.1	2.5
1970s	6.1	6.8	1.5
1980s	6.1	9.4	-0.9
1990s	5.6	9.6	0.2
2000s	5.3	7.0	1.0
2010s	3.8	6.9	0.4

Source: Author's calculations from Statistics Canada Tables 14-10-0204-01, 14-10-0261-01, 18-10-0004-01, and Historical Statistics of Canada.

2010s average calculated to 2019 to exclude impact of COVID-19 pandemic.

There is a visible although imperfect relationship between automation and factor scarcity and prices in Canadian economic history. Table 7 reports decade averages for Canadian business investment in M&E (as a share of GDP), along with two measures of labour availability: the average unemployment rate, and the average annual rate of increase in real weekly wages. During the initial expansionary postwar decades, business M&E investment was very strong (as described in Part II of this paper): between 6 and 7% of GDP. Labour markets were relatively tight (with unemployment below 5% for most of that period), and real wages grew rapidly (by 2.5-3% per year during the 1950s and 1960s). Productivity improvements associated with new technology were fully reflected in real wages. Strong business investment and low unemployment were mutually reinforcing: business capital spending was a key driver of rapid job-creation, while scarce labour and rising wages reinforced the incentive for businesses to invest in labour-saving technology.

This virtuous circle of innovation, job-creation, and rising wages weakened somewhat in the 1970s, as the economy was beset by oil price shocks and moderately higher unemployment. However, business M&E spending remained strong, and real wages continued to grow at a reasonable pace (1.5% per year) despite higher inflation.

With the shift to austere neoliberal macroeconomic policies in the 1980s and 1990s, however, this virtuous link between technology investments and living standards was broken completely. Unemployment soared to post-war highs (averaging over 9% through those two decades), and wages shifted into reverse. Real wages declined by

almost 1% per year during the 1980s, and remained stagnant in the 1990s. High unemployment, big cuts in income security programs (especially unemployment insurance), and a decline in union activity all contributed to the softening of wages over this period.

Despite these harsh labour market conditions, business M&E spending initially maintained its momentum from earlier decades. But after the turn of the century, technology investment slowed markedly. Chronic labour surpluses and weak wage growth likely played a supporting role in that investment slowdown. With abundant pools of unemployed and underemployed labour, and very weak wage growth, many employers were willing to stick with less capital-intensive, less innovative production methods. The resulting weakness in business investment spending in turn reinforced the sluggish performance of the labour market. The virtuous circle of the initial postwar decades (with strong M&E spending driving job and wage growth, which reinforced business motivation for new technology) was replaced by a vicious cycle of weak investment and innovation, stagnant wages, and chronic unemployment.

Labour markets have strengthened over the past decade, and real wage growth has shifted back into positive territory — although much slower than in the initial postwar decades (even the inflationary 1970s). Recent complaints of labour shortages in some industries, exacerbated by supply chain and operational disruptions associated with the pandemic, have led some employers to demand government action to replenish the available supply of low-cost labour. Standard prescriptions in this effort include opening up foreign migrant worker programs, and reductions in government income supports (temporarily boosted during the pandemic) to supposedly reinforce the "incentive" for workers to accept low-paid, irregular work.

According to the historical evidence presented in Table 7, however, this response would likely undermine the incentives for businesses to reinvigorate their investments in innovation and M&E. To the extent that scarce supply and rising prices for labour reinforce the incentive for businesses to adopt labour-saving technology, then government should ratify the labour-supply challenges facing employers today. Instead of mobilizing incremental pools of low-cost labour supply, governments should instead encourage firms to respond to a perceived labour shortage by stepping up their innovation activity. Some of the policies identified above (such as fiscal incentives tied to new capital spending) would further elicit business interest and action. Those incentives could be the "carrot" encouraging more investment in labour-saving technology — but a labour market characterized by scarce supply and rising wages should be the "stick."

Give Workers a Voice In Tech Change

We have shown that overstated fears about mass displacement of workers by robots and other automated technologies are not supported by empirical evidence on actual technological change in Canada's economy. And the obsession with technology as the main driver of workplace change distracts from more immediate and concrete

factors which affect work and workers: such as the growth of non-standard and precarious work, the erosion of collective bargaining in the private sector, and the underutilization of Canadians' already-impressive skills.

Nevertheless, ongoing technological change will have major impacts on Canadian workers and workplaces. Every innovation in products and processes raises implications for workers: Will there be an impact on hiring and employment in that specific workplace? Will workers require new skills? Will technology be used to make jobs safer and more pleasant, or more intense and repetitive? Will workers receive notice of changes in technology, opportunity to participate in decisions related to technology, and incentives or compensation if their jobs change because of technology?

Technological change is an issue where respecting and facilitating channels of voice and input for workers can clearly improve outcomes for employers as well as for workers. Innovations and technologies that look promising on a drawing board usually require adjustments or revisions in light of the experience of the workers who use them. Accessing that knowledge early in the innovation process, rather than encountering surprises and failures after new machinery has been purchased and installed, can make technological changes in workplaces more successful.

Modern digital technologies also raise important issues of labour rights and safety for workers, which can also be better identified, understood, and negotiated when workers have a consistent say in the process. For example, automated technology can raise important challenges of safety, ergonomic design, pace of work, and work environment. Workers need information and advocacy to effectively monitor these challenges, and respond constructively.

In short, workers will confront many important technological challenges in their workplaces in coming years, even though the pace of innovation and automation in Canada's economy is much slower than commonly assumed. These issues include the impact of technology on the quantity and quality of jobs, provisions for notice and negotiation over technological change, support for training and adjustment, and protections against the use of technology in ways that undermine health, safety, and privacy.[34] These are not new challenges: workers have been exposed to the uses and abuses of new technology since the Industrial Revolution, and have always sought ways to counter the unilateral power of employers over technological decisions. But new generations of technology demand a stronger ability for workers to engage in shaping and improving those processes. And for that they need an organized, effective voice, through trade union representation, collective bargaining, and other channels of input. By fostering more reliable, extensive, and safe channels of input and negotiation, a culture of collaboration around technological change can be built in Canadian workplaces. The experience of countries such as Germany, where co-determined technological plans are a normal feature of workplace relations (and where

[34] Stanford and Bennett (2021) catalogue the efforts of trade unions in Canada to negotiate specific contract provisions regulating the application and use of new technology in Canadian workplaces, organized into 12 different topic areas.

technological progress has been both consistent and mutually beneficial), suggest that strengthening worker voice on technology issues can be an important spur to stronger, and fairer, innovation.

Conclusion

IT WOULD BE WRONG TO SIMPLY DISMISS THE fears of many Canadians about the negative effects of automation and new technology on their job security. The empirical evidence presented above overwhelmingly suggests that labour-saving and labour-replacing technology in the real Canadian economy is slowing down, not speeding up, and there is no indication of widespread dislocation of labour from investment in machinery and equipment. Nevertheless, millions of Canadian workers experience pervasive insecurity in their work lives. They have endured stagnation in their wages, the expansion of insecure and precarious work in all its forms, and the erosion of their capacity to demand and win a better deal in an unforgiving labour market. In that context, viewing the onward march of technology as a threat rather than an opportunity is quite understandable. And there are many particular workplaces or occupations where Canadian workers have indeed lost their livelihoods as a result of the application of new technology – and in most cases were left without appropriate transition supports, income protection, or opportunities for retraining or redeployment.

However, while concerns about technological displacement are understandable, by digging deeper we can understand that it is the shift in the economic and institutional balance of power in our economy, not an acceleration of technology, which explains the pervasive insecurity and hardship which so many Canadians experience. Ultimately, technology itself is neither inherently useful nor destructive in its impacts on work, workers and living standards. Whether technology improves lives, or whether it leads to displacement, intensification, and surveillance, depends entirely on the social and institutional context in which new technologies are conceived, developed and im-

plemented. The experience of Canada's long postwar boom — when mechanization was faster than today — is proof that technological change can better our lives, so long as the economy is managed with a focus on bettering the well-being of those who work in it.

The common assumption that robots and other forms of automation are destroying chances for prosperity among Canadians workers is factually wrong. Worse yet, it diverts attention away from more immediate and damaging threats to jobs and incomes. The pace of business investment in innovation, technology, and machinery is in fact too slow for Canada to fulfil its potential as a global economic leader. Sustained weakness in innovation, M&E investment, capital intensity, and productivity are damning indictments of the failure of Canada's business sector to fulfil its assigned role as engine of economic dynamism. In part because of the failure of private-sector investment and innovation, Canada's labour market is increasingly dependent on industries and occupations which cannot offer long-run opportunity, prosperity and sustainability. This includes our growing reliance on low-productivity low-wage private service sector jobs, and a disproportionate and unsustainable dependence on resource extraction to pay our way in global trade.

For all these reasons, Canadian workers would benefit from more investment in robots and other forms of new technology, not less. The necessary revitalization of investment in innovation and technology must occur in the context of economic, labour and social policies which empower workers to participate in decision-making about technology, defend against its potential displacing effects, and share fairly in the resulting benefits (including better and safer jobs, higher real incomes, and more leisure time). And achieving stronger innovation and mechanization will also require a rebalancing of economic leadership and authority. We cannot continue to rely on the autonomous decisions of profit-seeking businesses to fundamentally determine the pace of investment and innovation, in their own interests. That reliance on business-led development has left Canada with our present underperforming economy. To achieve a more dynamic and innovative economy — one which is truly advancing both technologically and socially — we must challenge business decision-making, and give governments, workers, and communities a bigger role (and a bigger stake) in innovation, investment and technological change.

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